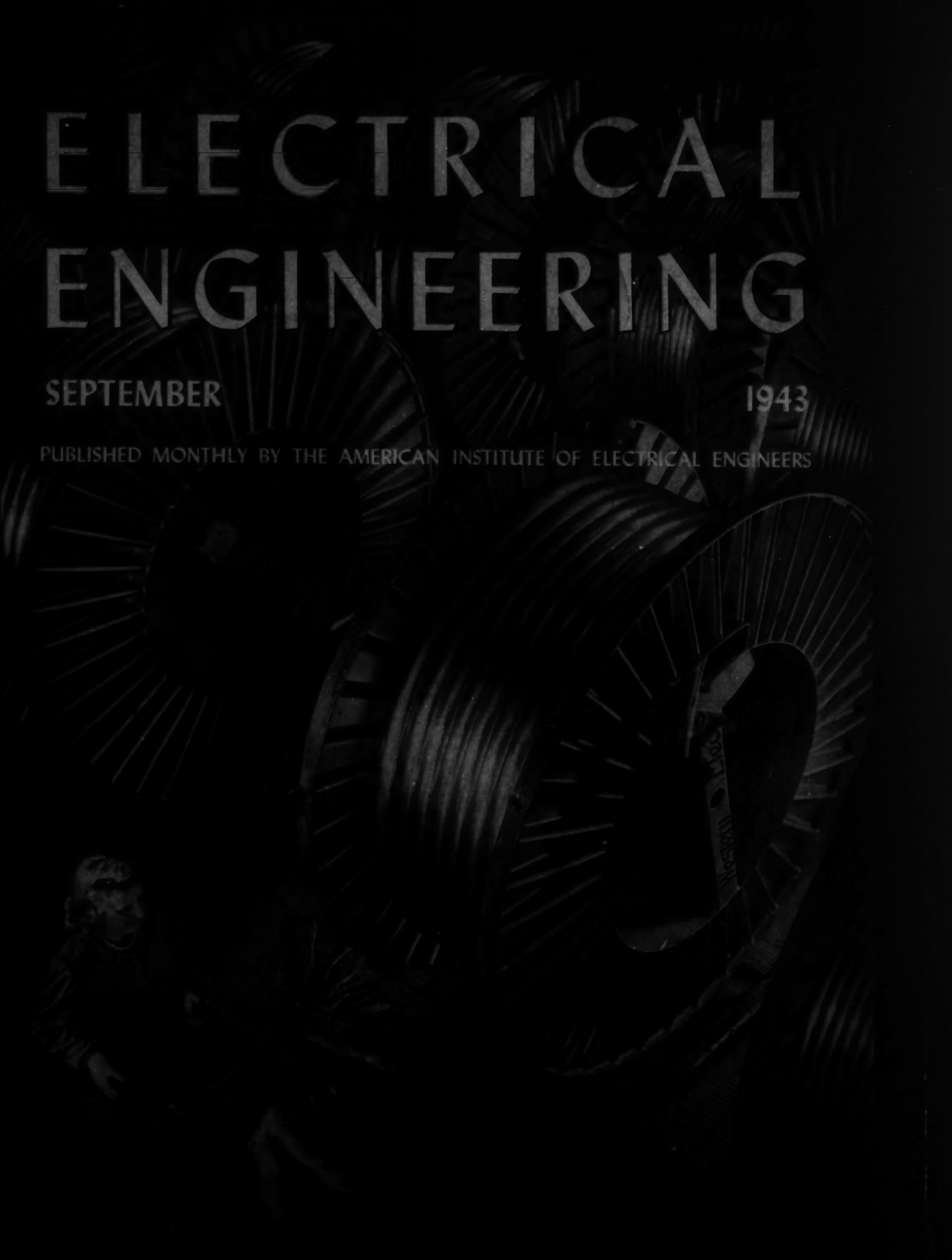
ELECTRICAL ENGINEERING

SEPTEMBER 1943

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS



He has a promotion to report. Or a week-end leave coming up. Or it's his mother's birthday.

Evening is about the only time he's free to call and it's important to him.

Will you do your best to avoid Long Distance calls after 7 at night, for the sake of millions of Joes — and Josephines? They'll appreciate it.

BELL TELEPHONE SYSTEM

Do you have any coil winding problems?

Let Belden Wire Engineering Service help you

Is your winding department faced with a tough coil winding job? If so, call in the Belden Wire Engineering Service.

Belden Wire Engineers are available, without obligation, to help your engineers or production men on any problem connected with magnet wire. For instance, they can help your staff in selecting the best type of wire insulation for a particular coil winding job. They can also determine the correct wire sizes and tolerances to meet unusual specifications.

Belden Wire Engineers have developed a number of simple tests for checking the quality of incoming wire shipments. If your winding department is not familiar with these winding tests, a Belden Wire Engineer will gladly demonstrate them.

Belden Dereeler speeds up coil winding by reducing spool changes. Write for bulletin.

In many cases, the Belden Wire Service has located the causes of winding machine troubles and has recommended adjustments in machine settings which have corrected long standing difficulties. In other cases, they have checked coil impregnation methods. Belden Wire Engineers will gladly help you at any time with similar magnet wire problems.

Belden Manufacturing Company, 4635 W. Van Buren Street, Chicago

Belden Magnet Wires

ELECTRICAL ENGINEERING. Published monthly by the American Institute of Electrical Engineers; publication office 20th & Northampton Streets, Easton, Pa. Editorial and advertising offices, 33 West 39th Street, New York 18, N. Y. Subscription $12 per year plus extra postage charge to all countries to which the second-class postage rate does not apply; single copy $1.50. Entered as second-class matter at the Post Office, Easton, Pa., under the Act of Congress of March 3, 1879. Accepted for mailing at special postage rates provided for in Section 538, P.L. & R. Act of February 28, 1925.

September 1945, Vol. 62, No. 9. Number of copies this issue 23,400

Superior varnishing characteristics

1. complete impregnation

2. higher dielectric

3. with less varnish build-up

4. fewer varnish dips

5. superior finish

KAPPA

Trade Mark Reg. U. S. Pat. Off.

● These definite improvements in the results obtained with the new Kappa Cellulose Acetate Rayon Tapes, when varnish-impregnated by standard methods, have been proved both by authoritative impartial laboratory tests and by the experience of many leading electrical manufacturers now using Kappa Tapes in regular production.

The KAPPA TECHNICAL BULLETIN gives in detail the results of tests covering both physical and electrical properties of varnished samples, together with specifications and prices. Ask for your copy of this bulletin, also for long length test samples of Kappa Tape in the widths and thicknesses you use. Kappa Tapes are IMMEDIATELY AVAILABLE in standard widths and consistent mil thicknesses . . . including 3, 5, 7, and 10 mil. Write to The Wm. E. Wright & Sons Company, Industrial Textile Division Box 1500, West Warren, Mass.

Complete test and Technical Data and prices in this new Bulletin. Free on request.

CELLULOSE-ACETATE RAYON

COIL-WINDING TAPES

The Wright tape for every winding..

KAPPA

We've only been knocking at that door . . . Midway . . . Guadalcanal, Attu, Buna, Munda . . . Tunisia, Pantelleria, Sicily. . . .

Magnificent actions all . . . but only steps that have brought us to the threshold of Victory.

Now it's here. *Invasion!*

But we've got to back these fighters with a fighting home front.

The 3rd War Loan Drive is on. The quota is $15,000,000,000.

The United States Government is asking you to invest in at least an *extra* $100 bond during September. But the job doesn't end there. We've got to get our family, friends and fellow employees to invest in their share of these victory-producing bonds and back the attack that has brought us this far.

Remember, this is what we've been waiting for. This is *invasion!*

back the attack with war bonds!

The Okonite Company, Passaic, N. J.

manufacturers of insulated wires and cables since 1878

Why

Rapid Fabrication of Large Parts

Molding has always been one of the fastest and most economical methods of producing plastic parts in quantities. But through a recent development of Bakelite Laboratories—Heatronic Molding—the technique of molding has been accelerated still further. Heatronic Molding employs electrostatic heating of thermosetting materials, so that heat is generated uniformly *within* the charge of molding material by high-frequency current. Curing time can be reduced 10 to 50 per cent, and molding pressures lowered by 30 to 40 per cent. Large-sized parts never before possible can now be produced on standard presses. For the first time, the compression molding of pieces thicker than ⅜ inch from thermosetting materials becomes commercially practicable. And, now, the impact-type phenolic plastics can be molded as readily as the general-purpose phenolics.

Manufacturers will immediately recognize the opportunities this process offers in the production of such large equipment as washing machines. The entire tub-and-gear housing could be completely formed as one unit, in a single operation, using the same sturdy and water-resistant plastic adopted for washing machine agitators. It would be strong and durable, yet light in weight. It would have highly desirable heat-insulating characteristics, and would be inert to caustic solutions.

TOUGHNESS for thin sections...

The development of plastic bayonets for Navy training purposes demonstrates the high tensile strength and flexural strength obtainable even for thin-walled parts when they are molded from BAKELITE Molding Board Materials. These impact-resistant plastics are supplied in sheets of various sizes, or in shapes cut to the approximate design of the finished parts. The blanks, as they are then called, are virtually preforms, which can be used in molds designed for general-purpose phenolics. Products can be made entirely from these materials, or the molding boards and blanks can be used with standard types of phenolic plastics to provide reinforcement at vital points.

LOW-COST metal replacement..

By adapting the plastic printing plate development of Bakelite Laboratories to the production of instrument control panels, one manufacturer is conserving impressive quantities of precious sheet aluminum and even more precious man-hours. A matrix of BAKELITE Phenolic Material is made from an etched copper plate, which serves as the original pattern. Any number of VINYLITE Plastic panels can be molded in this matrix, complete in every detail, and ready for subsequent curving to final shape by heat treatment. The combined use of these two materials assures faithful reproduction in one operation of not only the intaglio lettering, but also the hundreds of through-holes in the panel. It eliminates many operations necessary with metal plates, such as drilling, engraving, slotting, forming, anodizing, and polishing. *(Panels molded by Theo. Moss & Co., Inc.)*

DURABLE coatings that dry in minutes..

By the addition of BAKELITE Dispersion Resins to paint and varnish formulations, drying time can be reduced from hours to minutes. Such coatings, used by the Navy for more than 8 years as anti-corrosive aircraft primers, air-dry in 1 to 5 minutes without blistering or wrinkling, but nevertheless exhibit remarkable durability. Primers based on these resins and exposed, without top coat, for 2½ years on steel panels, revealed no checking or rusting. They have withstood 1,080 hours in a 3 per cent salt solution spray test, while other high-quality primers failed in 90 hours. They have shown no blistering, pimpling, or rusting after 8,000 hours of continuous immersion, whereas other primers failed in 300 hours.

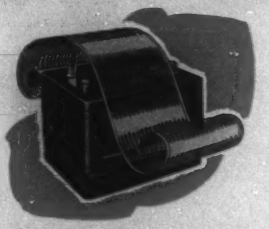
Helpful Literature on Plastics

These are a few of the valuable guidebooks you can obtain by writing to Department 27. "A Simplified Guide to Bakelite Plastics" is a 16-page summary of the principal BAKELITE Plastics now available. It describes each type briefly, and illustrates typical applications. "Bakelite Molding Plastics," a 32-page booklet, provides further information, and ASTM data, on moldable plastics. "Molding Technic for Bakelite and Vinylite Plastics," price $3.50 postpaid, is a 224-page manual on the art of molding plastics—contains comprehensive data that the designer, engineer, molder, and user should have on the design and fabrication of hot-set and cold-set molding materials. Additional pamphlets and booklets describing other types of BAKELITE Plastics are also available.

Plastics ?

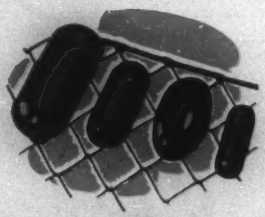
Remarkable DURABILITY for wood...

Stronger and lighter than metal, yet unaffected by extremes of heat or cold, oil, gasoline, and constant vibration, wood impregnated with BAKELITE Resins and molded into three-dimensional forms has become a most valuable structural material in the building of aircraft. Engine cowlings that resist high heat are representative of the many large shapes now molded from wood impregnated with BAKELITE Resin. Entire fuselages and wings can be formed. Sections as long as 84 feet have been successfully produced in torpedo boat construction.



RESISTANCE to corrosive chemicals...

BAKELITE Polystyrene Plastics, in the form of flexible sheeting, are now employed as storage battery separators. Like all other forms of this amazing plastic—molding materials, extruded rods, tubes, and filaments, and resins for surface coatings—the flexible film is unexcelled in its resistance to both alkalies and non-oxidizing acids. Other outstanding advantages of BAKELITE Polystyrene Plastics include: extreme lightness in weight with good mechanical strength characteristics, superior electrical insulating qualities particularly at high frequencies, and high index of refraction when crystal-clear types are employed.



Unusual water RESISTANCE and strength...

Because they are tough and flexible enough to withstand pressures encountered at underwater levels as deep as 1,000 feet, BAKELITE Polystyrene floats are able to release for other service the galvanized steel sheets formerly used to buoy commercial fishing nets at sea. The polystyrene material is extremely resistant to constant immersion in salt water, and also withstands the chemical solution used in cleaning and renovating the nets.

HARDLY A DAY PASSES but another new industrial development is made possible through plastics, or the usefulness of old, familiar products is increased by these versatile materials. Look for the reason and you'll find that the trend to plastics is much more than a matter of replacing other materials. It's because plastics frequently provide a better product, and generally one that is also more rapidly and economically fabricated.

Certain BAKELITE Molding Materials, for example, can give your products high mechanical strength approaching metals—with only a fraction of the weight of metal, and no need for time-consuming finishing. They can provide inherent corrosion resistance, electrical properties, heat resistance, color, transparency, translucency, or opacity. And a new molding technique now permits large parts to be molded at high speeds and in greatly increased sizes never possible before.

Wood becomes a stable and amazingly strong material when bonded or impregnated with BAKELITE Resins . . . releases steel in building construction . . . can be molded into heat-resistant and weather-resistant forms of varied shapes and sizes. Surface finishes fortified with one type of BAKELITE Resins dry within a minute or so, yet stand up in service far longer than many other high quality coatings that require hours to dry.

But these are only a few of the plastics developments now available to industry, and merely a suggestion of the vast opportunities they offer to designers and engineers. You can keep posted on plastics by keeping in touch with Bakelite Plastics Headquarters. Our Engineering Staff and Development Laboratories offer their full co-operation in helping you adapt a growing variety of plastics and resins to your essential needs. As a first step, write for the helpful literature shown here. Please address Department 27.

BAKELITE CORPORATION, 30 E. 42ND ST., NEW YORK
Unit of Union Carbide and Carbon Corporation

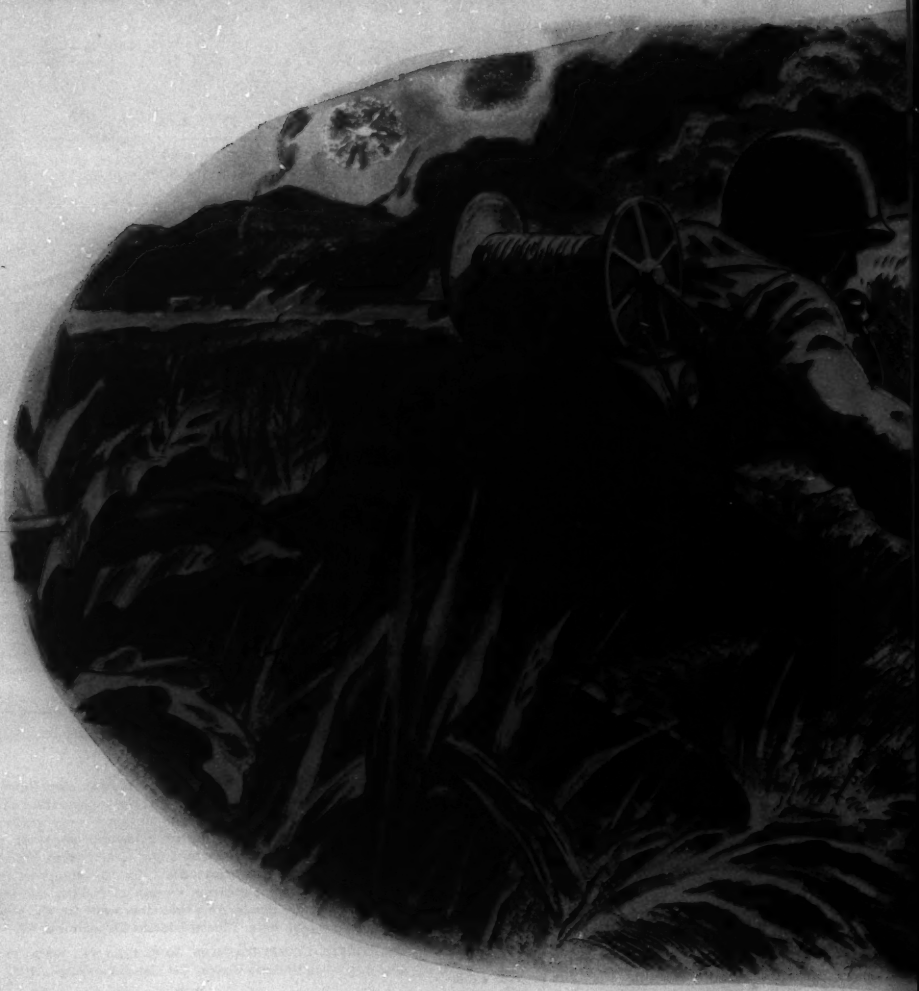
UCC

BAKELITE
TRADE MARK

The word "Bakelite" and the identifying products Symbol are registered trade-marks of Bakelite Corporation

PLASTICS HEADQUARTERS

WHEN OUNCES FEEL LIKE POUNDS

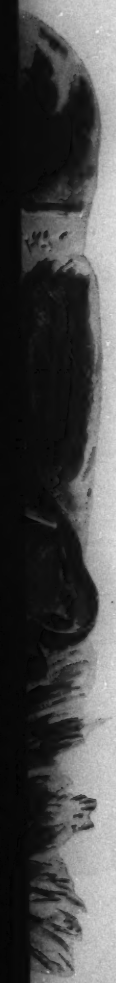


Reg. U. S. Pat. Office

1230 SIXTH AVENUE
ROCKEFELLER CENTER, NEW YORK 20

UNITED

...ASSAULT TROOPS USE LAYTEX*



You know how it is. You slog along all day under full equipment. At first you don't mind the weight very much. But as the hours crawl along, everything you're toting gets heavier and heavier. The canteen you didn't notice in the early stages now weighs as much as your rifle did then. And your rifle feels like a howitzer. Every ounce turns into a pound.

That's why . . . when you're moving fast and the going is tough . . . it's smart to use Laytex Assault Wire.

A full mile of Laytex Assault Wire weighs less than 30 pounds.

Laytex Assault Wire has a breaking strength of 50 pounds per conductor and a talking distance of more than 5 miles.

Laytex resists concussion and a wide range of temperature changes.

It is flexible and waterproof, strong and tough.

Conductors are accurately centered and the weight of insulation and the diameter of the insulated conductor are kept at the minimum.

All this adds up to the fact that one man, wearing a breast reel of Laytex Assault Wire can move swiftly and easily. One man can maintain sure communication with operational headquarters.

Listen to the Philharmonic Symphony program over the CBS network Sunday afternoon, 3:00 to 4:30 E.W.T. Carl Van Doren and a guest star present an interlude of historical significance.

STATES RUBBER COMPANY

A NEW TECHNIQUE *that is* SPEEDING VICTORY

LITERALLY a one man army, the paratrooper strikes fast and hard—almost anywhere. He represents a new and deadly technique of modern warfare, one that America is utilizing to the fullest.

Industry, too, has learned new techniques. New short cuts, new refinements in design, new ways to build faster and better the tools and weapons our fighting men need.

Simpson electrical instruments and testing equipment, for example, offer a basically superior type of movement which required a slow and costly method of construction only a few years ago. Today, in the Simpson plant, this greater accuracy and stamina is a matter of mass production.

Tomorrow the many things industry has learned under the impetus of war will build a brighter, happier world. The harder we work on the job at hand, the sooner that tomorrow will come.

SIMPSON ELECTRIC COMPANY
5200-5218 Kinzie Street, Chicago 44, Illinois

Simpson

INSTRUMENTS THAT STAY ACCURATE

Buy War Bonds and Stamps for Victory

NATIONAL ELECTRIC PRODUCTS CORP.
SPELLERIZED
SHERARDUCT
SCALE-FREE
PITTSBURGH, PENNA.
RIGID STEEL CONDUIT
NATIONAL
ELECTRIC PRODUCTS
"TO KEEP AWAY FROM RUST...
TO KEEP WIRING SAFE... RIGID
STEEL CONDUIT-SHERARDUCT"
WIRING 6 SYSTEMS
WIRES AND CABLES

From blast furnace to battle front...

Constant Voltage guides the Tools of War

NEVER before in the history of warfare has precision production been so important as it is today. From the trigger group of an M-1 rifle to the fire control of a 16-inch battery, split-hair tolerances are demanded in millions of intricate munitions parts. Producing to uncompromising standards requires the finest type of machine tools ever designed—operated at a constant level of electric power.

But *constant voltage* is almost non-existent on today's overcrowded power lines. Wartime consumers are busier. Huge volumes of electrical energy are being intermittently used and released. Heavy sags and destructive surges inevitably occur. For that reason, manufacturers in every field are stabilizing power themselves with SOLA CONSTANT VOLTAGE TRANSFORMERS.

Sola "CVs" equalize voltage sags and surges, absorb variations as great as 30%, feed a controlled flow of power to machines. And they protect the *very life* of sensitive instruments and electronic tubes.

Engineered for long, trouble-free service, Sola "CVs" are instantaneous in action, without moving parts, self-protecting against short circuit. They have a place on *your* production lines —the life lines of American victory.

Note to Industrial Executives: *Sola "CV" transformers are available in standard 10 VA to 15 KVA units. Special units built to specification. Ask for bulletin ACV-74.*

SOLA Constant Voltage Transformers

Transformers for: Constant Voltage • Cold Cathode Lighting • Mercury Lamps • Series Lighting • Fluorescent Lighting • X-Ray Equipment • Luminous Tube Signs Oil Burner Ignition • Radio • Power • Controls • Signal Systems • Door Bells and Chimes • etc. **SOLA ELECTRIC CO., 2525 Clybourn Ave., Chicago, Ill.**

ELECTRICAL ENGINEERING

Registered United States Patent Office

SEPTEMBER
1943

The Cover: Although one of the by-products of the war has been the increasing influx of women into industry, women workers are no novelty in the electrical field where they have been employed for many years in some of the more delicate operations. The girl on the cover is conducting an inspection test of telephone toll cable —Western Electric Photo by Holmes I. Mettee

Inter-American Affairs of Interest to the Engineer ..... Julian L. Schley . . . 385
Inter-American Co-operation in Standards ..... R. E. Zimmerman . . . 390
The Victory Twins—Electricity and Oil ..... H. E. Dralle . . . 393
Joseph Slepian—Lamme Medalist
The Lamme Medal ..... S. B. Williams . . . 400
Joseph Slepian—Engineer, Inventor, Scientist ..... L. W. Chubb . . . 401
The Fostering of an Engineer ..... Joseph Slepian . . . 403
Ultrashort Electromagnetic Waves—VI ..... Bertram Trevor . . . 405
Conductor Redesign Saves Copper ..... A. A. Osipovich . . . 410
Institute Activities . . . 412
Officers and Committees . . . 418
Of Current Interest . . . 423

TRANSACTIONS SECTION

(Follows EE page 428; a preprint of pages 563–610 of the 1943 volume)

Aircraft Contactors ..... F. J. Russell, A. P. Charbonneau . . . 563
Out-of-Step Protection ..... AIEE Subcommittee . . . 567
Distance Relay Protection ..... L. J. Audlin, A. R. van C. Warrington . . . 574
Method for Correlating Duty-Cycle Tests on Solenoids ..... J. E. Ryan . . . 579
Bushing-Current-Transformer Characteristics ..... S. D. Moreton . . . 581
Application of Lightning Protective Devices ..... AIEE Subcommittee . . . 586
Emergency Overloads on Overhead Conductors ..... AIEE Subcommittee . . . 588
Radio-Noise Filters Applied to Aircraft ..... C. W. Frick, S. W. Zimmerman . . . 590
Manual Switches for Aircraft ..... R. A. Millermaster . . . 596
Aircraft Inverter Construction ..... C. T. Button . . . 598
Fundamental Principles of Amplidyne Applications ..... F. E. Crever . . . 603
Wartime Conductor Temperatures for Power Cables ..... AEIC Subcommittee . . . 606

G. Ross Henninger
Editor (on leave)
Floyd A. Lewis
Acting Editor
F. A. Norris
Business Manager
H. A. Johnston
Advertising Manager

Statements and opinions given in articles and papers appearing in *Electrical Engineering* are the expressions of contributors, for which the Institute assumes no responsibility. ¶ Correspondence is invited on all controversial matters.

Published Monthly by the

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Founded 1884

NEVIN E. FUNK, President H. H. HENLINE, National Secretary

VOLUME 62
NUMBER 9

PUBLICATION COMMITTEE: H. H. Race, *chairman*; C. E. Dean; F. Malcolm Farmer; H. H. Henline; K. B. McEachron; John Mills; P. H. Pumphrey; C. F. Wagner; S. B. Williams

Electrical Engineering: Copyright 1943 by the American Institute of Electrical Engineers; printed in the United States of America; indexed annually by the AIEE, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index*; abstracted monthly by *Science Abstracts* (London). Address changes must be received at AIEE headquarters, 33 West 39th Street, New York 18, N. Y., by the 15th of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge.

Whether for beaming a headline across the world or bringing it into your home, Federal is a leading manufacturer of radio transmitting and receiving tubes, including the giant tubes used by Mackay Radio in its world-wide Communications Service

In your morning paper
It's only an arrow
Creeping toward a dot on the map . . .

But out there
Where the angry earth
Convulses under your feet
From the thundering steamroller charge
It's hell on wheels
As the tanks attack at dawn

• • •

And close on their clawing heels
Spattered with the same mud and lead
As the mopping-up forces
Comes the soldier with the typewriter . . .
The war correspondent

• • •

When you read his eye-witness account
Of how this town was taken
Read between the lines
And give a thought
To the man under the helmet
Whose only command is . . .
Get the story!

• • •

Helping him get the story *through*
Relaying it from field radio
To command outpost
To towering Mackay Radio
Trans-Atlantic radio telegraph station
Is the voice and ear of electronics
The vacuum tube . . .
Giving wings to his words
Just as it helps plane and tank
"Work together better
Because they can talk together"

• • •

Here at I. T. & T.'s manufacturing associate
Federal Telephone and Radio Corporation
Where a great many of these tubes are made
Our hats are off
To the men who use them
To speed victory . . .
Some day they'll help men
Build a better world

IT&T

International Telephone and Telegraph Corporation *67 Broad St., New York 5, N. Y.*
Manufacturing Associate:
Federal Telephone and Radio Corporation

Photo courtesy General Electric Company

View of Praca da Republica, Rio de Janeiro, with war department building in background

Inter-American Affairs of Interest to the Engineer

JULIAN L. SCHLEY

The engineer has an important stake in the progress of inter-American relations and an outstanding part to play in translating inter-Americanism into reality. The Office of the Coordinator of Inter-American Affairs and the Inter-American Development Commission both work to promote better co-operation and collaboration among the Americas.

THE SUBJECT of inter-American affairs, both as a war measure and as a permanent and growing relationship among great republics in this hemisphere, is a matter that grows in one's consciousness and interest; the more one thinks about it, the more he learns about it. The great wonder is that two decades ago we did not ourselves become conscious of that great need and what it would mean in the future to us in case of war and in time of peace, ultimately, if not immediately. The war and the development of inter-American co-operation have progressed to a point which makes this discussion timely. It is evident from the news that the tide of war is turning toward victory for the United Nations. The Americas united are playing a great role in the upbuilding of the growing strength of the United Nations. Working together, as they are now doing effectively, the American republics have become a powerful force in world affairs. I believe the Americas will continue to be the basis for postwar development of hemisphere resources, just as they are the basis now for wartime development.

Certainly no single technical group will have more to

Essential substance of an address at the AIEE national technical meeting, Cleveland, Ohio, June 21–25, 1943.

Major General Julian L. Schley is director of transportation, Office of the Coordinator of Inter-American Affairs, Washington, D. C. He was formerly chief of the Engineers Corps of the United States Army.

do with the economic development of the hemisphere than electrical engineers. The power age, as we well know, was making rapid headway in many of the other American republics prior to Pearl Harbor. Electricity was spreading its manifold benefits in improving the national economy and in making life better in neighboring republics, just as it has done here in North America. Still the power age in Latin America as a whole is far from the advanced development we know in the United States. But these countries have an urge to learn and to move ahead. Once the way is open again for resumption of normal industrial development, including electric development, I am sure we shall see long strides toward the utilization of the vast power potentials of Latin America. In this development, inter-American co-operation will provide a firm foundation for the linking of North American technical skill with the resources and industrial opportunities of our neighbors to the south.

In its broadest objectives, inter-American co-operation aims at making life happier and better for the average American. And that means the average American in the other Americas as well as in the United States. It is up to you engineers to help translate this worthy aim of inter-Americanism into reality. The material reality of higher living standards is represented by power plants, by transmission lines, by electrified industrial plants, by radios, washing machines, refrigerators, and the hundreds of other mechanical contrivances which have been fashioned from the miracles of electricity. These bring better living in a very real sense. And well do our neighbors to the south understand this. Their support of inter-American unity makes manifest their desire to join heartily in the advancement of hemisphere aims and the fuller use of hemisphere resources.

Today this co-operation is focused on the strengthening of hemisphere defenses and the mobilization of hemisphere resources in support of the United Nations. The Axis menace of aggression must be eliminated from the world before the Americas again can feel secure and free to pursue their long-range aims of building in this hemisphere a new world of happier living for the average citizen. Inter-American co-operation embraces work for the expansion of production of strategic minerals and at the same time, a large-scale development program to replace vital supplies formerly imported from the Far East and from other sources outside the hemisphere. This co-operation has brought new machinery for joint action among the Americas. It involves joint action in the construction of highways, airports, hospitals, and other facilities to meet immediate war needs. It includes co-operation in the removal of Axis influences from hemisphere airlines and from key industries.

Inter-American co-operation rests on the strong foundations of the good-neighbor policy. It is now ten years since President Roosevelt stated this policy at the start of his administration. Meanwhile, that policy has become deeply rooted in national thinking and acting in the United States. It has become established as a national policy, surpassing partisan debate. Progress in inter-American relations during this decade has been notable. It has been fortunate indeed in these last three crucial years that the United States has been able to strengthen immeasurably friendly relations with neighboring republics on the solid base of the good-neighbor policy.

This policy is expressed in the work of the Office of the Coordinator of Inter-American Affairs, an agency which aims to crystallize and bring into full power the co-ordination of all things leading to a proper understanding of Latin America. The office began in the summer of 1940 when the Coordinator, Nelson A. Rockefeller, arrived in Washington. France had fallen. Alone across the channel, England faced the Nazi war machine. Many on this side of the Atlantic were awakening to the grave peril of the Axis menace to the freedom of the Americas. In those dark days one bright beacon of hope was the growing mutual confidence and understanding among the Americas, resulting in steadily improving inter-American relations.

It was a somber period for the American republics. Latin America had lost the European continental market which had taken part or most of many of its major exports. On this side of the Atlantic, only United States industry had the capacity to turn out war machines to match and surpass the war machines of the Axis. For years, Axis agents in Latin America had been pursuing political, economic, and psychological warfare. This preliminary strategy, as we know so well now, usually is the forerunner of Axis military action. That pattern of Axis warfare has been re-enacted over and over in Europe and Asia. The Americas, with their rich and varied resources, were marked for conquest. The Axis strategists, in those somber days after Dunkirk, apparently were sure in their own minds that the Americas would never awake in time.

Today, we know that the Americas did awake. And how thoroughly and alertly they have awakened may be seen in the tremendous production of war equipment from these arsenals of democracy around the Great Lakes. The smoke of your factories, the clang of your forges, the hum of your assembly lines convincingly have answered the Axis propaganda line that democracy was outmoded, that it was too slow to save itself.

In those grim days of 1940 when the Office of the Coordinator of Inter-American Affairs was born, when we as a people were emerging from complacent thought that war might never reach these shores, there was much work to be done in the furtherance of inter-American co-operation. There was, for instance, the question of what the Americas would do to offset the loss of foreign markets. The Latin American republics, perhaps more than any other group of nations, had been peculiarly dependent upon foreign trade. They produced in the main staple products for export. With the proceeds of

these exports they purchased abroad most of their manufactured goods, their capital equipment, their shipping and insurance, and other services. The disruption of foreign trade, therefore, was a terrific blow to the economics of the Americas.

Realizing this, the United States took measures to help the Americas through this period. The Export-Import Bank of Washington placed at the disposal of the other Americas large credits to help stabilize their exchanges. The Coordinator's organization went to work to stimulate United States purchases in the other Americas, to improve commercial relations in every way possible, to hasten development of complementary industries.

Our armament program greatly facilitated these efforts to encourage inter-American trade. War production opened a huge market in this country for metals, wool, forest products, and other exports the other Americas previously had sold wholly or partly outside the hemisphere. Our imports from the other Americas in 1941 rose to approximately $1,000,000,000, nearly double the prewar level.

At the same time, the Coordinator's office initiated extensive work for the improvement of inter-American understanding. This work now covers a wide range in educational and informational fields. It includes the exchange of public authorities, writers, newspapermen, technicians, scientists, and outstanding personages in other fields, who contribute toward the development of the consciousness in the Americas of their common interests. As an example, a well-known Brazilian hydraulic engineer was recently invited to spend six months at the Vicksburg laboratory of the Engineers' Department of the United States Government at the department's request. This matter the War Department was extremely pleased to negotiate, not only because it will help Brazil to go forward in its water developments, but because it is a gesture of great value to us.

Such work has been responsible in large measure for the continued growth of mutual trust and confidence between the United States and the other Americas in the fateful years since the fall of France.

This work also includes the bringing of many young people to the United States from the other Americas for study and technical training. One of the most extensive of these training programs is in industry. Many young men from the other American republics have been brought to the United States to work and to learn at first hand in our factories, mills, business offices, agricultural establishments. Many young men also have been brought to the United States for aviation training.

Our colleges also are having difficult times now with the great load being thrown on them, different from the ones they are used to, and the training programs for cadets and arrangements for other special classes they are unaccustomed to. Anything that can be done through the AIEE to encourage the colleges to show a greater interest in these students we are able to bring up from Latin America to take special courses will be a help. These young men will return to their native countries where they will be among the leaders of the future. They represent a new generation of inter-American leaders who will help shape the further growth of inter-Americanism.

Likewise in this category are new technical schools and agricultural experiment stations which the United States, through the Office of Coordinator of Inter-American Affairs, has aided. These include a meteorological school in Medellin, Colombia; a business school in Bogota; a proposed engineering school at Caracas, Venezuela; and the newly established Inter-American Institute of Agricultural Sciences in Costa Rica. The meteorological school is particularly valuable from the air transportation point of view, since air movement becomes vastly safer when the weather conditions are fully known, and the absence of meteorological stations and perhaps the lack of appreciation of their importance are a great bar to safe flying. What these projects, and others like them, mean in the long run for the improvement of inter-American understanding and for the advance of technology you engineers well appreciate. These institutions are spear heads of technical progress. They will aid in the long-range improvement of inter-American living standards through the use of modern machines and production methods. The other Americas have the natural resources. What they need principally are capital, technical knowledge, markets, and freedom to pursue their aspirations. For help, they naturally look to the good neighbor in the north, just as we look to the good neighbors of the south for help in obtaining the vital materials we need to increase war production and to replace supply losses outside the hemisphere. This mutual aid emphasizes the natural foundation for co-operation among the Americas.

The work of the Coordinator's office, along with the work of other government agencies, underwent sharp readjustment to war needs after Pearl Harbor. At the Rio de Janeiro conference in January 1942 the American republics adopted a historic program to strengthen hemisphere defenses and to mobilize hemisphere resources. This program has been translated into action in the form of hundreds of projects for development of strategic materials, improvement of communications, large-scale health and sanitation measures, and expansion of food supplies. These projects are designed to meet immediate wartime needs. Yet they also create facilities for better national economy and higher living standards in the long run. The development of new industries; the construction of power plants and transmission lines, of hospitals, health centers, sanitation works; the extension of highways; the building of airports, warehouses and other durable works will remain after the war to become lasting additions to the productive and living facilities of neighboring republics.

Normal development of industry for civilian consumption since Pearl Harbor has been retarded or postponed in the other Americas, as in this country. The shipping shortage and the concentration of United States industry upon war work rules out today development of industries for consumer markets in neighboring republics, where this development depends upon the United States for machinery and materials. Still, much development work moves forward out of urgent wartime necessity. One example is Brazil's big steel plant at Volta Redonda, scheduled for completion in 1944. The Brazilian steel plant was undertaken before Pearl Harbor. It is proceeding with the aid of equipment and materials from the United States, partly out of recognition that Brazil must develop her vast resources of mineral, agriculture, and forest products to help supply United Nations needs. Brazil needs railroads to tap her immense hinterland, where minerals and forest products lie undeveloped. Once this steel plant has been completed, it will also serve for the long-range work of advancing production and living standards in Brazil. In this sense, the inter-American story is much the same as the postwar gains we stand to reap from the utilization of our own war-expanded capacity to produce steel, light metals, tools, airplanes, chemicals, and other industrial essentials.

Another example of strategic industrial projects which must go forward is the rehabilitation of key Mexican railroads. This project has been undertaken by Mexico in co-operation with the United States, through the Office of the Coordinator of Inter-American Affairs, and is being carried out by the Mexican Railway Mission, headed by Oliver M. Stevens, formerly of the Missouri Pacific Railway. The Mexican railroads are of increasing importance, as the results of a shift in traffic to overland routes and the expansion in production of vital materials in Mexico and Central America for United States war industry. Any movement by rail from Central America to Texas is of tremendous advantage, now that shipping is dangerous by sea. The wartime improvement in Mexico's railroads, like Brazil's steel plant, doubtless will make an enduring contribution to the welfare of our neighbor across the Rio Grande.

Still other examples are the extension of commercial airlines, which are carrying much of the passenger load and even some of the freight load formerly handled by ocean shipping; the closing gaps in the inter-American highway in Central America, which we hope will be finished before long as far as Panama; the construction of many new hospitals, health centers, and sanitation works as part of the inter-American health and sanitation program. Malaria and other diseases are among the first problems which must be considered in any development of economic resources in the Amazon Basin, in Central America, and in other hemisphere areas co-operating in the wartime development work. Food for the workers and their families also is of prime concern in the expansion of production of rubber, fibers, minerals, and similar strategic materials. For instance, in the great Amazon Basin there is plenty of water but very little food, and almost all the rubber workers have to be fed by importation of food into that vast area. These twin human necessities—health and food—have been recognized in the basic-economy program of the Office of the Coordinator of Inter-American Affairs. We have something like 20 floating dispensaries on the Amazon Basin, serving the Rubber Development Corporation's workers.

This brief summary leads to an appraisal of the situation today. Where is inter-American co-operation heading, particularly in the economic field? The currents are deep and well defined. They flow strongly along the course of closer inter-American co-operation, and this includes co-operation in the development of trade and industries.

What is being done in this direction is more than temporary—it is for all time, we hope, and will continue at an increasing pace. We hope also that it is being conducted on such a basis that it will become more and more self-perpetuating, and that ultimately we will be able to carry on without government aid.

The other Americas are accumulating substantial backlogs of purchasing power as a result of our heavy buying of strategic materials and their inability to spend these balances immediately on goods from the United States. In other words, our purchases of raw materials have now reached such a large sum, that their inability, in reverse, to buy from us, because of our war restrictions on strategic materials, has placed in their hands a tremendous amount of money which needs use. These are nest eggs for use in the postwar period when our war-expanded industry will be better equipped than before the war to supply many of the things the other Americas want, including steel, chemicals tools, machinery. Inflationary forces in the other Americas, bringing rising living costs, present a serious problem, just as the rising trend of living costs does in the United States. The solution of this problem, too, requires inter-American co-operation.

So far as one may rationalize on the basis of the visible factors, one reaches the conclusion that inter-American trade will remain at a high level for years to come. Many readjustments will be necessary after the war, just as many readjustments had to be made to war conditions. Thus far, the Americas have made these adjustments fairly successfully. They have learned to work together in mutual understanding. What they have achieved already prompts optimism in judging their capacity to make further adjustments as problems arise.

As for success in doing private business with Latin America, there is no magic formula. It is a matter of hard work, of tact, of intelligent understanding, of sincere effort to see the other man's viewpoint and to assure to him his share of the bargain. Those who

have had broad experience in business in Latin America see virtue in these suggestions:

1. Successful business in the other Americas should be on a development and not on an exploitation basis. Those who expect to make a quick and fat profit from Latin America, who are not prepared to stand a year or two of development expense, might do well to hesitate on future ventures.

2. The other Americas are not newly discovered markets. On the contrary, many large United States organizations have been doing business in Latin America for years. They have learned that fair dealings bring recompense, that a good-neighbor policy is just as fruitful in business as it is in diplomacy.

3. There are risks in doing business in Latin America just as there are risks in doing business in the United States. One source of risk is the failure of many people to realize that each of the other Americas is a separate national entity with its own special characteristics. Operations must be conducted under the laws and customs of the individual country. An organization planning to do business in the other Americas would do well to study the local conditions, customs, and laws before making extensive commitments.

Moreover, businessmen should remember that new mechanisms have been created for the encouragement of inter-American trade and industry. The Inter-American Development Commission and the development commission established in each of the American republics (21 in all) are among these new mechanisms.

The Inter-American Development Commission is an undertaking created by conventions of the 21 American nations in Rio de Janeiro, Panama, and other places. It is entirely independent of the war, for it was created considerably before the war and will last long after it. It is at the disposal of all businesses in the United States, and of every organization in Latin America and of their governments.

Mr. Rockefeller, the coordinator of Inter-American affairs, is also president of the Inter-American Development Commission.

This Commission has in each of these Latin American countries a subdivision or a national commission, composed of the nationals of that country, all prominent men who serve the main commission in their own country and are prepared to do all possible to increase its economic well being. The development commissions provide channels for collaboration between private interests and governments in the furtherance of new industries and trade. Their work should become of greater importance after the war when it will be practical to resume industrial development along more normal lines than is now possible.

Through such channels as the inter-American development commissions, government and business together assume jointly the widest possible responsibility for new enterprise, in contrast with fly-by-night exploitation. They are guided by local customs and laws and the broad objectives of inter-American co-operation.

The inter-American development commissions are not to be confused with government organizations. That group in Brazil, that group in Argentine, that group in Chile, which is a local commission of this IDC, has no relationship with its government, but it is a subcommission of the commission, created by the 21 nations in congress assembled.

As for the prospects of electrical development in Latin America, we are familiar with the estimates of the tremendous hydroelectric potentialities in such countries as Brazil and Chile. The Latin American countries are well aware of their latent power resources and of the possibilities of harnessing this power to the production of aluminum, to mining and manufacturing.

Lack of coal, now keenly felt, increases their incentive to develop electrical power. For wider use of these power resources, they need capital and equipment, as well as expanding internal markets for the power once it is developed. In many areas of high power potential, rainfall is sufficiently abundant to provide a good flow of water. There also are promising possibilities for the construction of water storage facilities and for projects of combined water uses.

With the development of these resources, one might logically expect to see interconnection of power systems. Postwar developments in Latin America may see a trend toward large base plants, supplanting in many localities small ones independently serving restricted territory.

The engineer has an outstanding part to play in convincing our neighbors that inter-American development will be a matter of mutual benefit to the countries participating. The AIEE members in Latin America can be of tremendous service to you in an understanding of the situation, of the possibilities in Latin America, because they are men who live there, they are men who know the conditions, they are men who have the reaction of what we do in this country, whether favorably or unfavorably. They know how business is conducted in those countries. They know the great importance of standards in production.

This brings me to one final observation: the electrical engineer has a very important stake in the progress of inter-American relations. The Americas are learning to work together for joint solution of common problems in an atmosphere of growing mutual trust. The many projects they are carrying on jointly today demonstrate this ability of the Americas to work together. The inter-American system of co-operation offers to a war-torn world a road to enduring peace and stability. This principle likewise offers a guiding principle for businessmen in search of a sound basis for the development of inter-American trade and new hemisphere industries. The inter-American way of co-operation and peace has been proved sound beyond debate. The methods of the Axis military powers only emphasize the merits of the inter-American system. Whether it is in foreign relations, inter-American trade, or engineering enterprise, the co-operative principle in the long run will yield the best results.

Inter-American Co-operation in the Development of Standards

R. E. ZIMMERMAN

Interest in international standardization is increasing rapidly in Latin America—to a considerable extent through the efforts of the American Standards Association which has sought ways and means of supplying more adequate American representation and co-operation in the development of standards. The program for the future includes exchange of technical data among the various American republics and development of inter-American standards to the advantage of all the Americas.

DEALINGS among and between peoples are facilitated when there is a common understanding among the parties involved, and, if the dealings relate to things or articles of commerce, then so much the better if the standards pertaining to their manufacture, performance, and acceptance are mutually understood and agreed upon.

International standardization is a matter which can be realized only in part, even where descriptive standards are applicable. National differences in aspirations, language, natural resources, physical equipment, and long-established customs and methods operate to mark off certain areas as favorable, others as unfavprable, for the spread of international standards. The International Electrotechnical Commission has accomplished much in bringing about practically world-wide uniformity in units, measures, and nomenclature. Such agreement upon the use of a common set of scientific designations has facilitated greatly the interchange of technical information. Less marked have been the results secured thus far by the International Standards Association, in which this country, through the American Standards Association, is represented along with 21 others. Although its world-wide activities necessarily have been interrupted for the period of the war, the international association has made substantial progress on a selected group of projects. In general, to whatever extent the international acceptance of practically identical or equivalent standards has been found feasible, in like measure have benefits been conferred upon science and industry and upon the peoples they serve.

Inter-American co-operation in the adoption of standards, from our standpoint, presents some conditions which are different from those involved in collaborating with the highly industrialized nations of Europe. Organized standardization in the other American republics is of relatively recent origin, as compared with the set patterns prevailing elsewhere. Moreover, in quite a number of the Central and South American nations, standards and specifications are of preponderating interest as applied to imports, rather than to domestic production. In certain countries, however, the consideration of domestic production is coming more and more into prominence, and the pace is rapidly accelerating. So likewise is the awareness of the value of standards, as applied to all classes of products.

Hemispheric security and solidarity have a special significance for all of the American nations during a period of global war. Mutual help in overcoming a common enemy calls for pooling resources and working together with the highest possible degree of understanding. Minds must meet and things must fit. Strategic materials are needed now and will be needed later, regardless of name. In numerous material ways interchangeability enters the picture, and standardization is indicated.

Good-neighbor policy stretches over periods of both war and peace and provides for the exchange of benefits in all fields of endeavor. It is our hope that what we have learned in the development and use of standards here in the United States may qualify as one of the items of benefit in the series of exchanges which will mark our living and working together with these neighbor republics.

Exports to the Americas and imports from them are bound to have an important relationship to standards and standardization, if commercial intercourse between and among the republics is to be facilitated. In the United States, producers of goods for export are deeply interested in markets throughout this hemisphere, as well as elsewhere. They have something to offer, many things needed in Central and South America, and expect acceptance only on the basis of price, quality, and service. On the other hand, it would be strange if the other American republics did not wish to offer their products in the markets of the United States.

In furtherance of both of these aims, it is to the interest of the parties concerned that the standards adopted for application to the articles of commerce be appropriate in every respect. One of the matters over

Essential substance of an address at the AIEE national technical meeting, Cleveland, Ohio, June 21–25, 1943.

R. E. Zimmerman is vice-president in charge of research and technology of the United States Steel Corporation, New York, N. Y., and is currently president of the American Standards Association.

which we in the United States are solicitous is that the standards which are being formulated by the countries actively interested in the movement toward standardization be not drawn in such a way as to exclude our goods or to place them at an arbitrary disadvantage with the products of other exporters. Many of us in the United States do not realize the extent to which foreign competitive influences have been at work in the American republics for the purpose of bending proposed standards in that very direction. Because of our failure to apply adequate measures of co-operation during the periods when specifications and standards were being formed and technologists of other nations were hard at work on the scene, there is already a considerable handicap to be overcome. The present world situation affords us an opportunity, if we will embrace it properly, to make up in co-operation what we have omitted over a period of years.

It must be said, in justice, that the condition described as pertaining to the American republics, although characterized by inadequate measures, has not been one of utter neglect. From time to time various governmental agencies, such as the Bureau of Foreign and Domestic Commerce and the National Bureau of Standards have lent a helping hand with respect to specifications. Some years ago a number of the standards of the American Society for Testing Materials were published in Spanish and Portuguese and distributed. More recently that society's standards on refractories were translated into Spanish; the Argentine government oil fields published the ASTM petroleum standards, and the Argentine Cement Institute translated and distributed the standard specifications for concrete.

As early as 1924, on the initiative of several of the South American countries, a Pan-American conference on standardization was held at Lima, Peru, in connection with a scientific conference under the auspices of the Pan-American Union. Again, two years later, a second such conference was held in Washington. Considerable work was done, but practical results were meager.

During 1941 the division of engineering and industrial research of the National Research Council conducted a tour of industrialists through Latin America in the interest of increased co-operation. The Inter-American Safety Council, founded in 1938, co-operates with the accident-prevention associations in some 20 American republics by supplying information on safety codes and methods. Its membership comprises more than 1,000 industrial units employing in the aggregate about 1,000,000 workmen. In this field of co-operation desirable progress is being made.

Collateral contacts of value are maintained throughout the Americas by our five engineering societies through resident members in various countries, by the exchange of bulletins, and by various services performed. Memberships that now exist in the other Americas are of the utmost importance in any of the work of collaboration that we can hope to carry on. These societies, for example, have a Joint Committee on Inter-American Relations which is planning to print, in Spanish and Portuguese, a digest embracing a large number of papers which should be of interest to engineers. Again, the AIEE and the American Standards Association have had a joint committee concerned with certain special phases of inter-American standardization. The work of that committee is done, and it is not functioning now, but the work that was stimulated by the collaboration is being carried on.

Due mention must be made of the valient services performed, over a period of years, by the American Chamber of Commerce in Buenos Aires. In the absence of any other agency, members of this body have kept in close contact with the standardizing institute of the Argentine, assisting in every way possible with the formulation of standards and carrying the American point of view into the proceedings. This chamber in Buenos Aires has likewise played a most important role in effecting plans for organized full-time American representation in the standardization movement in South America.

As mentioned heretofore, interest in standards is increasing rapidly in many of the American republics. Among the more prominent standardizing bodies already set up and functioning are the following:

Mexico: On January 1, 1943, the Direccion General de Normas Nacionales, or Department of National Standards, was organized to replace the former Department of Weights and Measures. The present organization has quite a wide program for standardization. It is governmentally sponsored but is in quite close touch with the work that is going on in the United States, and, as an aid to the operations in Mexico City, an advisory committee, with representatives from five American interests located in Mexico, is proceeding to help the Department of National Standards.

Photo courtesy General Electric Company

Coya hydroelectric plant, Chile

Argentina: This was the first Latin American country to establish a national standardization body. It is called Instituto Argentino de Racionalizacion de Materiales, and it functions much like the American Standards Association.

Brazil: Here the Associacao Brasileira de Normas Tecnicas, similar in constitution to the ASA, takes care of the work of standardization. Another institution, the Instituto de Pesquisas Tecnologicas de Sao Paulo, performs some of the laboratory functions of a national bureau of standards. It is our understanding that these two bodies work in close collaboration, but the recently organized and functioning Association of Standards is taking care particularly of the standardization work in Brazil.

Chile: At present there is a government department which issues mandatory standards for electrical equipment. In November 1942 the first Chilean Engineering Congress recommended the establishment of a designated standardization institute. The movement is well supported, and the expectation is that an institute will soon be organized and functioning in Chile.

Uruguay: The Instituto Uruguayo de Normas Tecnicas is a recently organized body but is busily engaged with a large number of standards.

In other countries not listed here, standardization is being handled by different agencies whose operations are being followed with interest.

The American Standards Association, for more than five years past, sought ways and means of supplying more nearly adequate American representation and co-operative effort in matters pertaining to standards in South America.

When I use the word, "American," I mean all of the Americas. Naturally, we are interested in carrying the ideas of the standardizing bodies of the United States as far as we can, but we realize that there must be a meeting of minds, and that this is a co-operative effort, so that the American point of view means the point of view of all the Americas.

Through correspondence and contacts of long standing this need for American representation and co-operation was clearly recognized, and the urgency of the situation was emphasized repeatedly by members of the American Chamber of Commerce at Buenos Aires. Similar views had been expressed by committees of the American engineering and technical societies, by trade associations, and by members of industry. During the summer of 1942 a succession of events brought the awaited opportunity to crystallize plans and to take definite measures toward enlarged inter-American collaboration.

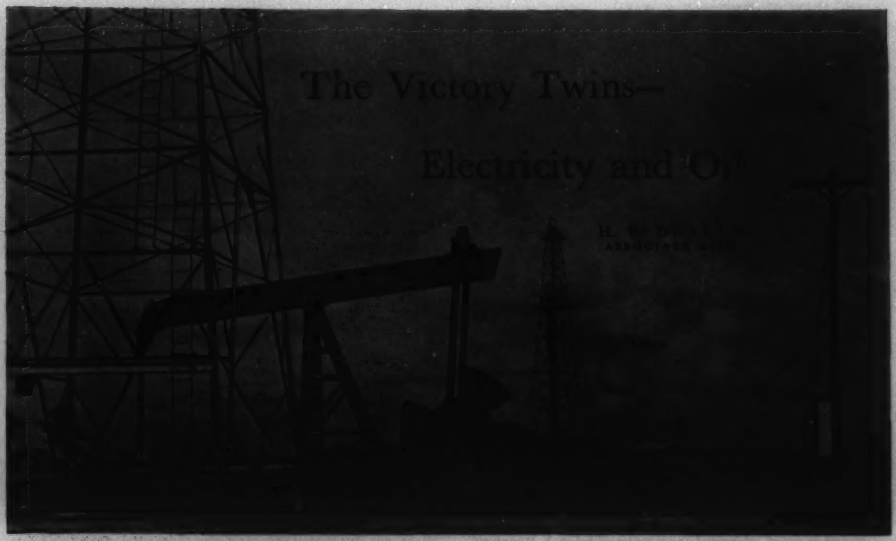
In its approach to the project the American Standards Association had the advantage of counsel from an advisory committee, composed of individuals from such organizations and agencies as the Bureau of Foreign and Domestic Commerce, National Bureau of Standards, American Society for Testing Materials, Chamber of Commerce of the United States, Export Managers Club, National Foreign Trade Council, and several industrial concerns with long experience in matters of standardization as applied to export goods. Most fortunately, the association also had the advice, assistance, and endorsement of the Office of Coordinator of Inter-American Affairs in its endeavors, which was most helpful in perfecting the requisite arrangements.

After the completion of the necessary formalities, the American Standards Association established an inter-American division in its New York office in December 1942, headed by a man of long experience in Spanish and Portuguese markets. As field representative in South America the association was fortunate in securing the services of an engineer and sales executive who has spent many years there and is thoroughly acquainted with the language, customs, and needs of various countries. His headquarters will be in Buenos Aires, where he has lived for several decades. Representation in Brazil has been provided by enlisting the part-time services of a sales executive who is also head of the technical committee of the American Chamber of Commerce in Rio de Janiero. It is hoped that this work will be enlarged very shortly and that full-time representation will soon be available in several of the important centers of Brazil.

According to the new program, the American Standards Association will exchange technical data with the other American republics in the development and use of standards, furnish information on the standardization work being done in the United States, and provide them with Spanish and Portuguese translations of standards which may be of special interest and value. In general, the idea is to provide such a thorough interchange of technical data and information that as a result, all of the countries of the Western Hemisphere will have standards as much alike as possible.

We must not allow ourselves to believe that this initial step, gratifying as it is, is a completed task. It is a move in the direction of adequacy, but only a small one, in view of the field to be covered. A definite beginning, of the right sort, we think, has been made. The undertaking, however, is extremely large, both geographically and from the standpoint of things to be done. We shall have to work extensively, but should be equipped to work intensively in certain areas at the same time. Do not forget that our alert competitors from the Eastern Hemisphere have been tilling the ground systematically for a long period of years and that representatives from the United States must quicken their efforts to overcome existent handicaps.

The American Standards Association, acting on behalf of its constituents, and with the indispensable assistance of its advisory committee on inter-American co-operation, is making a determined attempt to fortify and enlarge its initial undertaking, to the end that the opportunities now open in the field may be met and that mutual good may result therefrom. All parties who are interested in the wider spread of inter-American co-operation in the adoption of standards are assured of a hearty welcome as supporters of the movement.



The Victory Twins—Electricity and Oil

H. E. Dralle
Associate Member AIEE

Electricity is indispensable in the finding and drilling for oil, and in the pumping, refining, and transportation of oil; electricity and oil are the victory twins which shall aid us in fighting and winning the war, declares this specialist in the application of electrical machinery in the oil industry.

MANY products will be required in the winning of the war, but no two are more essential than electricity and oil.

Since both oil and electricity are forms of energy, it might appear at the outset that they are always competitors. But far from that, they are close collaborators. Electricity today officiates at the discovery, bringing forth, and development of oil into refined, useful, and necessary products. Conversely, oil is essential to the generation of electricity as insulation, lubrication, and often as fuel. Thus they are indispensable to each other, and have virtually become victory twins.

Although petroleum—oil—is one of the oldest natural products used by man, its origin and the extent of the supply stored in the recesses of the earth are still a matter of conjecture. Each generation, each decade, brings forth new truths to add to the ever-growing petroleum lore and to disprove the errors and deficiencies in our theories of yesterday.

The uses of oil are as old as history. Down through the ages it has been closely associated with the accomplishments and advances of civilization. Oil and natural gas seeping to the surface of the earth unquestionably furnished fuel for the fire to which primitive man paid devotion. The fire worshippers (Zoroastrians) built their altars near the burning gas wells at Baku (Russia) on the Caspian Sea; and today a shrine there marks the early manifestations of what was supposed to be a great imprisoned spirit.

The ancient peoples used petroleum in primitive ways centuries before the Christian era. Noah's band calked the ark with "pitch," evidently a form of petroleum gathered from the shores of the Dead Sea. Little Moses' basket which floated among the bulrushes was also lined with pitch. Nebuchadnezzar's masons used asphalt as mortar in his Babylon palace. The "slime" used as mortar in building the Tower of Babel and other ancient structures is believed to have been petroleum.

Numerous legends indicate that the Greeks recognized the usefulness of oil. They destroyed a Scythian fleet by pouring oil on the sea and setting it afire. Belisarius, a famous general of the later Roman Empire, adapted this idea of using "burning water" in his campaign against the Vandals in Northern Africa; he smeared swine with oil, ignited the oil, and then drove the blazing, squealing, cooking porkers into the ranks of the terrified enemy. The Chinese are known to have used both oil and natural gas.

Essential substance of a paper presented before the AIEE Pittsburgh Section December 8, 1942 and before the Philadelphia Section February 8, 1943.

H. E. Dralle is manager of the petroleum and chemical engineering section of the industry engineering department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

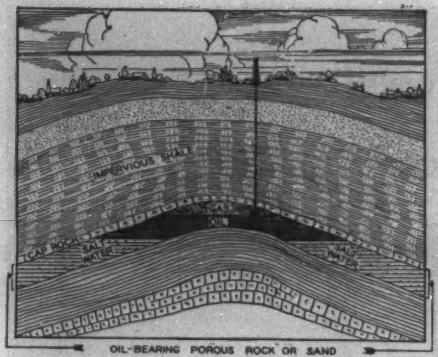


Figure 1. Oil trapped in nature's reservoir

But for all its varied uses, petroleum is mentioned most frequently in legend and in history as a curative for all of the ills of man and beast. The early Europeans coming to America found the Indians using crude oil as a medicine. Even within the span of our own lives, opportunities were plentiful to purchase from a "corner" dispenser an innocent-looking bottle of "Seneca Oil," guaranteed to cure any bodily ailment falling between the limits of dandruff and flat feet.

In this simple medicinal stage, the consumption of petroleum imposed no great problems of production; however, when the values of petroleum for lubrication, fuel, and other refined products were realized, its uses grew to proportions that even the most imaginative could not contemplate and that most of us still do not appreciate fully. Deprive us of oil with its gasoline, lubricants, plastics, rubber, explosives, perfumes, face powders, and thousands of other items that contribute to the high-standard American way of living, and our life rhythm would slow down to a snail's pace.

But, fortunately, we are not going to be robbed of petroleum and its products which are destined to play such an important part in the victory which must be finally ours. A continued supply of some of the most vital war materials is assured from the more than 500,000 producing oil wells in the world today. Even though we have lost control temporarily of some of these wells—in Poland, Rumania, Russia, Java, Sumatra, Borneo, Burma—this does not affect our operations too seriously, as the United States is blest with abundant oil supplies—over 60 per cent of the world's total. The combined output of the fields that have fallen into Axis hands and are temporarily lost to us is but 10 per cent of the world's total. Over 85 per cent of the world's oil supply is still under Allied domination, and over 70 per cent of this is in America. We have, therefore, direct control of production to meet the severest war demands. On the other hand, the very small supplies now available to the Axis very well may mean an abrupt ending of their resistance. If their limited day-to-day production had not been bolstered by tremendous storage reserves, their mechanized activity would have suffered more noticeably even before this.

WHERE OIL IS FOUND

In a span of less than 85 years the gigantic oil industry has grown from a small beginning to its present proportions which account for an annual consumption of about 2,000,000,000 barrels. Fast-moving and changing world events are constantly increasing the demand for oil. To keep pace with the growing requirements of the times America must lead the world now—as she has in the past—in the development of new and improved methods of finding, producing, refining, and transporting oil and its essential products.

Contrary to popular belief oil is not found in underground pools, but is held in porous sands or rocks, illustrated in Figure 1, much the same as water can be held in a sponge. When an oil-bearing sand is tapped, gas pressure forces the oil to the opening, and we have an oil well. In the early days of the industry, "oil witches," "peach twigs," and other supernatural devices were used for divining the presence of oil. Drilling near cemeteries or on the right-hand forks of certain creeks and other superstitious notions also had their day. Playing "hunches" in finding oil deposits is still somewhat in evidence, but the modern search for oil is conducted along scientific lines. Application of scientific knowledge, made possible in large measure by electricity,

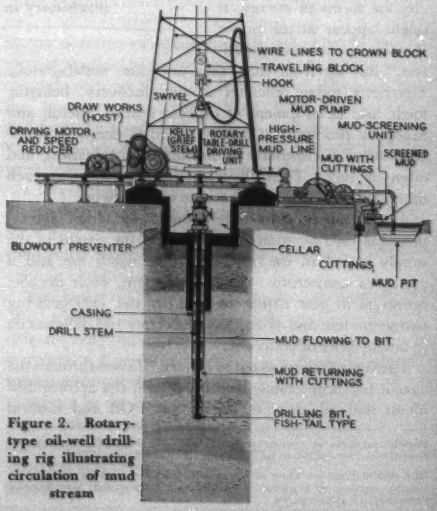


Figure 2. Rotary-type oil-well drilling rig illustrating circulation of mud stream

goes far in removing many uncertainties regarding the existence of formations favorable to oil deposits, but does not assure definitely the presence of oil. Only by drilling can we tell whether an oil pool lies hidden beneath the earth's surface.

The first oil well to be drilled (as distinguished from digging) was in Titusville, Pa., and is now known historically as the Drake well. Completed within the short time of four months to the astounding depth of 69½ feet, it was drilled by the method now known as "cable tool"—employing an old steam engine, a hemp rope, a steel bit, and a crude wooden windlass. This experiment proved the soundness of the idea of *drilling* for oil and marked the beginning of modern drilling methods, by which it is possible not only to drill a few thousand feet in several days, but to reach the existing record depth of almost three miles.

DRILLING

Let us consider briefly the drilling technique to see how electricity has helped in drilling, in the United States alone, more than 350,000 producing wells, varying in depth from a few hundred to 15,000 feet. If all of the wells which have been drilled were combined to form a single excavation, it would make a sizable tunnel (about 14 square feet in cross section) through the earth.

Today the most common form of drilling is by the rotary method, illustrated in Figure 2. The steel derrick which may be as much as 160 feet high supports, lowers, and raises by block and tackle the sections of piping used for drilling and casing the well.

The "bit" or "cutting tool" is attached to the lower end of the round hollow drill stem, made up of 20- to 40-foot joints of special drill pipe, and screwed together to any length the depth of hole requires. At the upper end is a hollow square section called the "Kelley" or "Grief stem" which passes through a square hole in the table to permit rotating the entire length of drill pipe and bit at speeds up to 350 rpm or even higher, depending upon the earth formation encountered and type of bit used. This table may be driven directly by a separate motor or by a chain from the hoist motor. Horsepowers as high as 250 are required for the rotating operation.

As the bit rotates, cuttings result. These cuttings are carried to the surface by the mud stream, drawn by reciprocating pump from the mud pit, pumped down through the drill pipe, out of the bit, and up through the annular space between the drill pipe and the walls of the hole, back to the mud pit, completing the mud-pumping cycle. Motors up to 400 horsepower are used on these pumps.

The other important part of the drilling rig is the draw works (Figure 3) which rests on the derrick floor. The draw works includes a multispeed hoist, on which is wrapped the cable that extends through the crown block (in the top of the derrick), and the traveling block

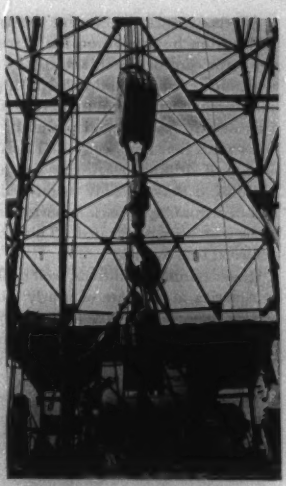


Figure 3. Draw works and traveling block on drilling rig

to form the "block and tackle" which supports the drill pipe. As drilling progresses, the driller allows the drum to rotate, "paying out" cable and thus permitting the drilling tool to progress downward. When the upper end of the "Kelley" reaches the rotary table, another section of drill pipe is inserted, and drilling is resumed.

Figure 5 shows a typical motor rated 400 horsepower, 900 rpm, for driving the draw works. Note the separate motor atop the main motor to supply safe cooling air to the main motor, which often operates on heavy loads at very low speeds and hence would have difficulty with self-ventilation.

With well drilling to depths of two and even three miles, the mechanical problems become increasingly important. It is difficult to realize that, if the bit at the end of a drill pipe 15,000 feet long should stick, electric meters at the surface instantly would record increased load, but several seconds would elapse, and there would be 15 to 20 complete turns of the drill pipe at the top before the table would stall.

As drilling depths have increased, the *need* has also increased for greater power in order to permit wells to be completed within reasonable time. It is not uncommon now to drill completely a well 10,000 feet deep within a month. Contrast this with the Drake well which required about four months to drill 69½ feet. It is not many years since electric motors of 250-horsepower rating on the hoist of a drilling rig were considered large. Today 600-horsepower motors are in use and 800-horsepower motors are being contemplated. The largest electric drilling rigs in existence are of the d-c variable-voltage type, having a total continuous generating capacity of 1,200 horsepower, and utilizing, on the draw works, motors rated 600 horsepower. Obviously short-time or peak loads greatly in excess of these can be handled. The capital investment in such electric-power equipment may run as high as $70,000 to $75,000, which is only one third of what the total investment may be on the drilling rig.

All this electric equipment too is controlled by the driller from his station on the derrick floor. Figure 7 shows the control wheels and meters used on a variable-voltage d-c drilling equipment. In principle, the functioning of this equipment is similar to that of an elevator—it is smooth, flexible, and powerful, for handling easily tool strings that may weigh 100 tons or more.

In well drilling, electricity has many other uses, in addition to those already mentioned. It is used at all well depths to bring back important subsurface evidence of the structures penetrated. This technique is known as electrical well logging.

Under normal conditions, well drillings are completed in America at the rate of nearly 30,000 per year. At present, however, because of restrictions due to shortages of critical materials, drillings are completed at the rate of only 20,000 per year. Of this number almost 23 per cent come in dry and are called "dusters."

These new drillings are necessary to locate new reserves, to supply more oil to meet the constantly increasing demands, and to meet the production requirements for wells that have been abandoned.

OIL WELL PUMPING

When a well has been completed in a productive sand, the gas pressure may be sufficient to bring the oil column to the surface. In such case the well is said to "flow." With decreasing gas pressure, flow rate decreases until it is necessary to raise the oil to the surface by some method of pumping. In this operation again, electricity is particularly useful, whether the wells are pumped in groups by means of central pumping powers (a common form of pumping for light wells), or singly as individually operated and self-contained units.

In the individually operated wells we may have both the electric motor and the centrifugal pump at the bottom of the well. In this type of unit both motor and pump are integrally connected and supported from the tubing which carries the oil to the surface. Leads for supplying electric power to the motor are clamped to the tubing. This type of submersible unit is particularly adaptable where large volumes of fluid are to be handled. Often only a very small percentage of the total fluid is oil, the rest being salt water.

The most common form of individually pumped well is the type in which the reciprocating pump is supported by the tubing at the bottom of the well and is actuated by a string of sucker rods mechanically connected to the walking beam and the electric motor on the surface.

Formulas developed from a series of comprehensive tests utilizing electric instruments and magnetic strain gauges in recording simultaneously stresses at 14 different points in the mechanical pumping system between the motor on the surface and the pump at the bottom of the well, enable one to calculate the horsepower rating of the motor to apply on any well. Such motor-driven wells are particularly adaptable to automatic operation, with electric time clocks which automatically start and stop, at prescheduled times, wells that should not be pumped continuously. Automatic operation greatly increases the number of wells that can be attended by a single operator and, at the same time, minimizes the possibility of errors attendant on manual operation. The opposite extreme is illustrated by a native-owned, hand-operated pumping well in Burma, where eight to ten men and women raise to the surface from a single 300-foot well 15 to 20 barrels of oil in one day. Instead of one man operating 25 to 30 wells, as is entirely possible with automatic time clocks, here are 10 or 12 persons on a single well. Oddly enough, that particular field at Yenangyoung, which is now under Jap domination, is over 95 per cent electrified for all operations—perhaps the most completely electrified field in the world.

OIL TRANSPORTATION METHODS

Since our areas of greatest production and refining of oil are quite remote from the large centers of population, oil transportation becomes for us an important economic problem. The millions of barrels of crude oil brought to the surface daily must be delivered to refineries where the oil can be broken down into its usable products, and these refined products, in turn, must be delivered to their points of use. In the transportation of oil and its products, the most generally used means are tankers, pipe lines, barges, railway tank cars, and trucks, in the order of their cost per barrel of oil handled. If we assume that we wish to get oil from the Gulf Coast of Texas to New York (2,000 miles by tanker, 1,600 miles overland), the transportation costs per barrel by the different methods are approximately as follows: tankers 20 cents; pipe lines about twice that much; railway cars about twice as much as the pipe line, or four times as much as by tanker.

Since the tanker provides haulage between coastal points at the lowest cost per barrel, this method was used chiefly before Pearl Harbor to bring, from our Gulf Coast and the South American countries, the 1,400,000 barrels of oil required daily on the Atlantic Seaboard. The submarine menace, as well as the diversion of tankers to lend-lease and other activities in both the Atlantic and Pacific, made necessary the employment of other methods of getting the much needed oil to the Eastern Seaboard from our Gulf Coast and midcontinental areas. Although efficient use of existing railway tank cars, barges, and trucks has made it possible to provide the East with over 800,000 barrels per day, to obtain the necessary additional oil the pipe line offered the most expansible method, appraised from the standpoint of least time and power required and the least expenditure of critical materials.

More tank cars would require more locomotives; more barges would require more power boats, more canals, and canal improvements; more trucks would require more rubber and more man power. Expenditures in critical materials and horsepower for these improve-

ments had to be weighed against increased building of tank ships and related convoy equipment. So steel and power became the controlling factors in the selection of pipe lines as the most desirable method of expansion.

Children of this situation are the world's largest products line and the world's largest and longest crude-oil line. Both are electrically welded and electrically operated. The products line, known as the Plantation Pipe Line, running between Baton Rouge, La., and Richmond, Va., is made up of 12- and 10-inch diameter pipe for the main line to Greensboro, N. C. (800 miles), and 8- and 4-inch diameter pipe for the branch lines (650 miles). This line takes in daily at Baton Rouge 90,000 barrels of refined products of eight different grades (gasoline, kerosene, Diesel fuel, and others) and delivers them at odd points in the South and Southeast, over its 1,450-mile length as efficiently as a railroad delivers fruits and vegetables from Florida to New York.

Tenders of oil are dispatched through these systems much the same as trains are dispatched on a railroad. Deliveries of products from a pipe line may be made simultaneously at a number of different points, and some points may require shipments to different marketing companies. In the case of the Plantation Pipe Line, the complex and ever-changing dispatching function for the entire line is centralized in a dispatcher's office in Atlanta. All pumping stations and delivery points are connected to the dispatcher's office by a teletype system providing continuous recorded intercommunication. From the dispatcher's office are issued all orders governing the routine operation of the line, including starting and stopping of stations and individual units within the stations. Without electricity in these many diversified applications—communications, power, lighting, automatic control—these operations could not be carried on so effectively.

Figure 4 shows the interior of one of the main pumping stations of the Plantation Pipe Line. These 900-horsepower 3,600-rpm, totally enclosed fan-cooled explosion-resisting motors (the largest of their type ever built) drive centrifugal pumps that daily push through the

Figure 4 (below). Interior of Plantation Pipe Line pumping station showing 900-horsepower 3,600-rpm explosion-proof squirrel-cage motors—the largest of this type ever built

Figure 5 (below). 400-volt 900-rpm d-c motor connected through reduction gear to draw works. The explosion-proof motor-driven blower brings safe ventilating air to main motor

Figure 6 (above). Central pumping power operating 16 wells from a single motor

Figure 7 (right). Control wheels on draw-works post at driller's position for operating world's most powerful d-c variable-voltage drilling rig. Load meters in full view of driller on derrick floor

1,450-mile system the 90,000 barrels of refined products.

Starting and normal stopping of these individual units within each station are controlled by the station attendant. Prevention of starting and protective shutdown of units and stations are accomplished automatically when conditions arise that exceed preset safe limits of operation from the standpoint of either temperature or pressure. When automatic shutdown results from such excesses, not only is an audible signal given to warn the station operator, but a light indication of the specific protective function is also given to permit quick and easy attention to the part in distress.

The duties of the attendant incident to the starting and stopping of main-line units are simplified by providing in one complete-sequence automatic operation for the valves, motor control, and pressure devices concerned. Thus relieved from a routine performance of manual operations at different points in the station, the operator can devote his attention to the over-all process and to the results obtained.

One of the critical features of multiproduct-line operation is the prevention of intermixture of different successive shipments called "tenders" as they move end to end through the line and the pumping stations. To accomplish this, it is necessary to maintain velocity in the line higher than a critical minimum amount. At any lower velocities, a phenomenon akin to laminar flow takes place, with greatly increased intermixing. Obviously, this places an unusual premium upon the reliable operation of the pumping equipment.

Oil travels through a pipe line at three to five miles per hour; consequently, about nine days after a product is started through the line at Baton Rouge, it would make its appearance at Greensboro, over 800 miles away. Of course, it would not appear until the line is completely filled. The Plantation Line has a storage capacity of more than 500,000 barrels.

The new 24-inch crude-oil line, popularly known as the "Big Inch" line, now being built between Longview, Tex., and the Eastern Seaboard by War Emergency Pipe Line Company, a distance of 1,388 miles, will have a storage capacity of approximately 4,000,000 barrels, the equivalent of one day's production of all the wells in the United States, or 65 per cent of the world's daily total oil production. Here are some other interesting facts about this world's largest crude oil line:

1. It is now practically completed between Long View, Tex., and Norris City, Ill.—550 miles in less than six months after starting. By June 1943, it will be fully completed to the Seaboard, 1,388 miles.

2. It will handle 300,000 barrels of oil daily.

3. Its carrying capacity is equivalent to 85 notional tankers averaging 75,000 barrels capacity and operating between Gulf ports and Eastern Seaboard (about 2,200 miles) at a ten-knot speed.

4. The pipe line will increase deliveries to certain overseas points with no more steel than would be required for tank ships in comparable delivery, with savings in power, man power, and money cost.

5. The line will operate at 750 pounds pressure.

6. It is powered by 126,000 horsepower in main motors in the form of 84 units, each rated 1,500 horsepower, 1,775 rpm, and generally arranged in 28 stations with three motors per station. It will have three pumps in each station operating in series.

7. Power for the 28 stations will be supplied by 16 different power companies between Longview and the Seaboard.

8. Eight different contractors worked simultaneously in welding electrically and laying the 24-inch pipe on different sections of the line. As many as seven miles were laid in a single day.

9. The line required about 365,000 tons of 24-inch steel pipe, having a wall thickness of $^{1}/_{16}$ inch. It will deliver 0.82 barrels of oil per day per ton of steel used, which is about a standoff, when compared with a tank ship, in steel efficiency. This figure compares with 0.50 barrels per day per ton for barges and 0.52 for tank cars.

10. There is some talk of stepping up the capacity of the line from 300,000 to 450,000 barrels per day. This would require 250,000 additional horsepower, or 200 per cent increase in power for 50 per cent increase in capacity.

The economic and transportation changes requiring the building of such large lines have also required supplying other feeder lines from important producing fields and the modification and actual reversing of other lines already operating. Among these projects were reversal and conversion of a Texas company pipe line between Port Arthur and Dallas; reversal and conversion of the (Atlantic Company) Keystone line (now crude oil) across Pennsylvania, from Pittsburgh to Philadelphia; enlargement of the Shell line from Wood River, Ill., to Lima, Ohio; reversal of the Sun-Susquehanna products line from Cleveland to the Eastern Seaboard; reversal of the Standard Oil Company of New Jersey Tuscarora pipe line from the Ohio–Pennsylvania border to New York; enlargement of the Texas Empire line between Tulsa and Chicago; opening of a new products line across Florida (35,000 barrels per day), and numerous others.

In addition, other larger oil lines will be in process before the end of 1943. A 20-inch products line to par-

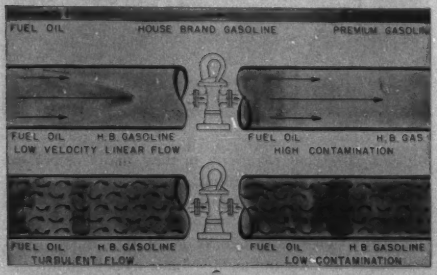


Figure 8. Diagram showing how a pipe line transports different products. To minimize contamination, velocity is maintained in the turbulent range

allel the war emergency crude line is being built and may be completed to the Eastern Seaboard by the end of 1943. If it is, electric power of the order of 100,000 horsepower will be required to operate it.

REFINING

Consideration should also be given to the economic contributions which the refining branch of the oil industry has made in supplying our constantly expanding armada of ships, planes, tanks, and mechanized equipment for war. Long and patient research by the refiners over the years has transformed crude petroleum into a veritable treasure chest from which are now being obtained a thousand and one needed substances—aviation gasoline, toluol, new alcohols, acids, solvents, perfumes, pharmaceuticals, special lubricants, organics, and synthetics of every type, including rubber.

Not long ago it was believed that the ultimate in motor fuel would be reached by creation of a gasoline equivalent to pure iso-octane in power and antiknock qualities. So superior was iso-octane in these qualities that it arbitrarily was given a number of 100 to become the standard by which all gasolines would be evaluated. But this was before the battle of Britain.

The epic fight of the Royal Air Force to save England, and incidentally the democratic world, was also a chemists' fight to produce fuels that would get planes into the air in shorter time and permit them to fly faster and farther than their adversaries. The American chemists of our refineries were in the fight, because they knew then and know now more about fuels than any one else on earth. The battle of Britain became a developing and testing laboratory that has brought forth changes in motor-fuel technology, the effects of which will be in bold evidence long after the war. Fuels are already being made that go beyond the octane scale—estimated as high as 125 octane—that will produce 50 per cent more power than 100-octane fuel. The large quantities of this fuel that are available have enabled engine and airplane designers to produce more powerful and speedier planes. The importance of this superior fuel is being demonstrated graphically as the American air program moves into full swing.

Toluene, best known as the basis of one of the most important high explosives (TNT), used in shells, grenades, depth bombs, and aerial torpedoes, is a refined product of petroleum.

Special lubricants, so highly important to military forces on land, sea, and air, must function efficiently under the exacting and varying conditions of modern warfare. They, too, are products of petroleum refining.

And now synthetic rubber—the crowning achievement of the refinery. Pearl Harbor and the quick succession of grave events that immediately followed placed us in the position of "have nots" from the standpoint of natural rubber on which our daily lives so greatly depended.

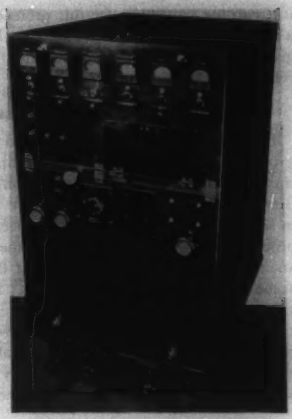


Figure 9. Portable mass spectrometer for analyzing gases accurately and quickly, qualitatively, and quantitatively

The present rationing program brings home to us the importance of this commodity to our very existence and gives us a better appreciation of the Herculean task undertaken by industry of producing synthetic rubber at a rate that will permit our obtaining much for civilian use in 1944. The most prolific source of the base materials of synthetic rubber is petroleum, and the refineries have moved rapidly in changing their plants to provide large quantities of butadiene and styrene in order to produce new rubberlike material of even broader and more promising utility than natural rubber.

The perfection of cracking processes that permit greater yields of materials for rubber production has the practical effect of increasing enormously the Nation's petroleum reserves and in extending the usefulness of oil.

In all of these developments, electricity has been a worthy victory twin of oil—they have grown to man size together.

Changes in refinery operations to meet specific demands for many specialized products have necessitated, not only the increased use of electric power, but also new and improved types of electric apparatus to meet exacting operating requirements in refineries. Provision of testing facilities to permit the furnishing of underwriters' labels on explosion motors of ever increasing horsepower ratings are being expedited. On present applications requiring explosion-proof motors of these higher horsepower ratings, it has been customary to follow construction practices that have proved successful for smaller ratings. Such motors are built with mechanical parts suitable for operation in both corrosive and explosive atmospheres. These are getting the job done in good fashion.

Control equipment, too, has been improved constantly to provide greater safety, to conserve space, and to simplify installation—all in keeping with the accelerated program of doing more, safely, in less time with less man power. As heavy spot loads have been added to electric systems already well loaded, it has been necessary in many plants to make power-distribution and system-stabilization studies to apply equipment of proper

interrupting capacities for full protection of apparatus and the power circuits. The calculating board has greatly facilitated these studies and has increased the reliability of the systems.

ELECTRICAL ANALYSES

Both the 100-octane-gasoline and synthetic-rubber programs necessarily deal with complex hydrocarbon mixtures, the analysis of which is long and tedious by present fractionation methods. More accurate analyses in shorter time are desirable. Electricity will solve this problem too by means of the mass spectrometer, which analyzes mixtures by separating out different elements according to their molecular masses. Samples as small as one cubic centimeter at atmospheric pressure may be easily analyzed. Intensive co-operative research is now going on to make this electrical analyzing device an everyday tool for important laboratory analyses, and its use may be extended even to process control.

In the marketing phase of the oil industry, too, electricity is definitely allied with oil. A small explosion-proof electric motor, automatically set in motion by pressing the valve on the filling-station hose, pumps into your car the weekly three gallons of gasoline; and for pumping up your tires an automatically operated pressure-controlled motor-driven compressor supplies the air. In the good old days in the memory of all of us, in fact in 1942 B.R. (before rationing) there were 450,000 such service stations in America, each with one or several such pumps. No doubt many of these will shut down, but there still will be left a goodly number in our filling stations.

And so we see that in all phases of this large and essential oil industry, electricity is indispensable and has shown itself a worthy Victory twin for oil. Its numerous uses everywhere have greatly accelerated accomplishments and simplified our task of becoming the "filling station" of the democratic nations of the world.

Joseph Slepian—Lamme Medalist

The Lamme Medal

S. B. WILLIAMS
MEMBER AIEE

UNDER the terms of the trust established in the will of Benjamin Garver Lamme, who died 19 years ago, was the stipulation that the Lamme Medal shall be given annually "to a member of said society (AIEE) who has shown meritorious achievement in the development of electrical apparatus or machinery." The donor of this award was one of those American electrical immortals whose basic discoveries and teachings will live to inspire electrical men as long as there is an electrical art.

Some awards are made to perpetuate a man's name—they are monuments to his contributions to progress and serve the noble purpose of stimulating others to emulate his determination. Mr. Lamme, however, had an entirely different idea in mind when he inserted that provision in his will. He was a modest man and sought no honors in life; neither did he wish for them posthumously. To him an award was a living vital thing, provided it stimulated initiative. All his life Mr. Lamme was interested in men and in helping them do that for which they were best fitted and talented. This award, therefore, represents the unwillingness of a man to let the grave prevent him from encouraging endeavor. Death could not and did not silence that spirit.

"For his contributions to the development of circuit-interrupting and circuit-rectifying apparatus," Joseph Slepian was presented the AIEE Lamme Medal for 1942, which was established by the will of the late Benjamin Garver Lamme, at the recent AIEE national technical meeting in Cleveland, Ohio. This 15th presentation ceremony was opened by S. B. Williams, chairman of the Lamme Medal committee. L. W. Chubb outlined the achievements of the medalist.

But Mr. Lamme left this world a generation ago at a time when the electrical industry had not yet reached its maturity. He lived during that period when great engineering individualists not only flourished but were necessary for the exploration of vast new uncultivated areas. But as an art matures, and narrowing frontiers change development from one that is extensive to one that is intensive, many specialists take the place of the few big

S. B. Williams is editor of *Electrical World*, New York, N. Y.

minds that had wide vision. More and more we see development come by way of collaboration of these specialists.

On the other hand, as long as the art is strong and vigorous, we shall have new machinery and new apparatus. In this respect Mr. Lamme's vision has bridged the two decades since his death and will bridge many many more.

In the past we have been able with this award to recognize a brilliant array of individual achievements. And this year's medalist will add further luster and glory to the award through the brilliance of his research.

But change is taking place today—change from individualism to collaboration. Those who had the privilege of being close to Mr. Lamme know that he was an advocate of change. He cared not who was responsible for change—1 man or 20—provided there was progress. If he were living today, would he not interpret "for meritorious achievement" to mean also the direction and stimulation of the collaboration that resulted in new and important forms of electrical machinery and apparatus?

It seems to me, as it does to others on this and past Lamme Medal committees, that some way can be found, without lowering the bars, to acknowledge this change in research responsibility while perpetuating this recognition of achievement that Mr. Lamme had in mind when he inserted this provision in his will. We owe it to him, and we owe it to those splendid electrical engineers who have received this medal, to maintain the dignity of the award—we also owe it to succeeding generations to maintain the stimulus to great deeds afforded by the donors.

A medal is a living thing. Properly awarded, it grows in prestige with the years.

Joseph Slepian—Engineer, Inventor, Scientist

L. W. CHUBB
FELLOW AIEE

To the uninitiated, award of the Benjamin Garver Lamme Medal to Joseph Slepian seems remarkable, because the recipient was never formally trained as an electrical engineer. We who know the man and his work see nothing unusual in his selection for this honor, because we realized long ago that he is one of the great engineers of our time.

But Doctor Slepian is more than an engineer. Trained as a mathematician and a physicist, he is a true scientist and a prolific inventor. Most inventors have a high percentage of accidental triumphs, but Slepian's successes are the result of theoretical analysis and the dreams of a scientific man. He has always found his solution by seeing a need, analyzing the situation, working out a method on paper, and proving it in the laboratory.

Some years before the copper-oxide rectifier was invented accidentally, Dr. Slepian's mode of scientific reasoning led him to the conclusion that there should be an asymmetrical conduction across the junction between copper and copper oxide. He built such a rectifier with layers of copper oxide and copper, but it required an accident in which the oxide was formed on the parent metal to catch up to his theory.

Some of his inventions were so far ahead of the times that the patents expired before they were extensively applied. Two of these are in the field of electronics—the electronic multiplier, depending on secondary emission, which was issued early in 1923, and an electron accelerator, issued in 1927 and just now becoming of great interest in production of high-energy electrons.

As an engineer, Doctor Slepian is unique in that his education and early experiences all pointed him toward an academic career. Son of an immigrant Russian tailor in Boston, he was a brilliant student of mathematics and science in the public schools and entered Harvard University at the age of 16. He was graduated in 1911 and remained at the university until he received a doctor's degree in mathematics in 1913. As a Sheldon fellow, he spent another year as a postdoctorate student at the University of Goettingen in Germany and at the Sorbonne in Paris. When he returned to America, he became a mathematics instructor at Cornell University and, as far as anyone could tell, was permanently rooted in the academic soil.

Fortunately for the profession to which we belong, he did a sudden about-face, resigned his instructorship, and started an adventure which resulted in his enlistment in the ranks of industrial research. He came to the Westinghouse company as a graduate student, winding coils and doing other shopwork by day, and studying electrical-engineering volumes at night. This unusual grafting of a practical knowledge onto a mind already fully developed for theoretical thinking has resulted in a scientific engineer of rare excellence.

If Doctor Slepian had never left the classroom, I am sure that he would have ranked among the leading university men of these times. Our profession can count itself fortunate that he became one of us, and I often speculate on how much more slowly we would have progressed in the last two decades without Joseph Slepian.

He has approximately 200 United States patents issued and many more pending in radio, electronics, measurement, electrochemical processes, electrical machines, lightning arresters, acoustics, X rays, materials, systems of transmission and distribution, high-voltage phenomena, circuit interrupters, vapor electric devices, control, and other fields.

L. W. Chubb is director of research, research laboratories, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

His papers, which we have learned to admire as beacons marking out the path of engineering progress, cover many fields but are particularly numerous in the fields of high voltage, arc extinction, circuit breakers, rectification, and lightning protection. Since his award is for developments in circuit interruption and rectification, I would like to call attention to some of his papers on these subjects.

His interest in circuit interruption has been continuous since his first patent covering a circuit interrupter in 1919. In his paper "Extinction of A-C Arcs," presented before the Institute in 1928, is the first statement regarding influence of circuit-voltage recovery rate on circuit-breaker arc extinction. Another paper entitled, "Extinction of Long A-C Arcs," presented in 1930, was the first to show the influence of gas motion or turbulence in oil circuit breakers, expulsion fuses, and gas-blast switches. A third paper presented at about the same time made the first statement that an arc has a growing dielectric resistance before current zero. These accomplishments of Doctor Slepian were the stepping stones to development and design of better breakers.

Joseph Slepian

His fundamental work on high-voltage phenomena, lightning arresters, and spark gaps also contributed to improvement of circuit breakers. I remember his 1928 paper on breakdown of spark gaps which originally presented the idea that space charges in the path of the first electron avalanche, distort the field and greatly accelerate breakdown, accounting for the speed of breakdown and streamer formation in spark gaps at atmospheric pressure. This theory, not widely held by those working in the field at that time, is now generally accepted by the experts in mechanism of high-voltage breakdown.

In the field of rectification, Doctor Slepian has made a direct and dramatic contribution to the safety and progress of our nation. One result of his invention and experimental development in mercury vapor devices is the Ignitron, which is in great measure responsible for the enormous production of aluminum and magnesium required for our military aircraft.

At the beginning of 1940, all industry—electrochemical transportation, central station, steel and others—had rectifiers totaling 500,000 kw in operation or on order. This represented the production of a 15-year period. In the three years since commercialization of Doctor Slepian's Ignitron, five times this capacity, or 2,500,000 kw of rectifiers have been purchased in this country, and another 1,000,000 kw have been purchased from Canada to meet the demands of war production.

The Ignitron is an outstanding improvement over former types of multianode rectifiers. Its arc drop and, therefore, the losses are approximately half of those in a conventional rectifier.

But in telling you about Slepian the engineer, inventor, and scientist, I have neglected to give you a picture of the man. My first talks with him took place 27 years ago when he submitted to us an invention for indicating a ship's speed by measuring the voltage generated in a transverse conductor, cutting the vertical component of the earth's magnetic field, and completing the circuit by electrodes in the still water on each side of the ship. That sea speedometer never amounted to much, but I believe the discussions led to employment of this unusual scientist in industrial research.

From our shops he graduated to the laboratories where he did routine and developmental testing of electrical apparatus. In a matter of weeks older and more experienced engineers were including the scholarly young tester in discussions of their problems.

When he first arrived at the engineering laboratories, I happened to be in charge and in a position to recognize his unusual qualities.

On one occasion the rest of us were so busy on some development that I could not assign Doctor Slepian to a new job at the moment. Instead of marking time until we had finished, Slepian asked my permission to study a complicated setup of large motors, electrolytic condensers, reactors, instruments, transformers, and disorderly wiring and cables in a nearby room. Permission granted, he traced the circuits and made a complete schematic diagram of the system on a large piece of paper. He did not recognize the electrolytic condensers, and I explained them to him.

Without any further assistance, he deduced that the setup was designed to explore operation of polyphase induction motors from a single-phase power line. He not only learned about this specific problem but went on from there, in a short period analyzed the general problem of phase conversion, and made several inventions for both static and rotating phase splitters. His initiative and independence have not lessened during the years since then.

Another incident in those days demonstrated his ability to tackle the most difficult assignments. Another laboratory employee whose job it was to make special tests on large machines with oscillographic apparatus was absent on a day when a short-circuit or buckover test had to be run on a large commutator machine.

Doctor Slepian was assigned to take his place, despite the fact that he was not an engineer, had never used an oscillograph, and had never been assigned to such an important and high-power test.

He did that job without missing a single picture. He did it in a scientific manner, studying the portable apparatus, learning all about the connections and controls of the complicated six-element unit, and supervising the entire setup. Even an experienced tester feels a certain timidity in handling high-power tests, but Doctor Slepian proceeded with aplomb, because he knew exactly what he was doing and why he was doing it at each step.

He is a born consultant with the ability to give a clear explanation in language exactly on the technical level of his listener. His enthusiastic, willing, and helpful attitude brings his clients back time and again with new problems.

Doctor Slepian is still a comparatively young man, only 52. He has crowded much hard work and many solid and brilliant accomplishments into those years. We who know and esteem his remarkable ability and scientific honesty expect him to spend many more years in valuable research and fruitful development work.

If Mr. Lamme could have been present at the meeting of the medal committee, he would have been pleased by the selection of Joseph Slepian. Lamme, the engineer, would be able to appreciate the contributions that Slepian has made to the development of electrical apparatus and machinery.

The Fostering of an Engineer

JOSEPH SLEPIAN
FELLOW AIEE

Doctor Chubb has emphasized my own personal role in the technical developments which form the basis for this much-esteemed Lamme Medal Award. However,

Joseph Slepian is associate director of research, research laboratories, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

man does not work in a vacuum, but lives in an environment of things, men, and ideas, which react on him and upon which he reacts. My own environment during my professional life has, in large part, been that aggregation of buildings, tools, money, men, ideas, and traditions, known as the Westinghouse Electric and Manufacturing Company, a corporation organized for manufacturing electrical machinery for the profit of its stockholders. That environment must have been propitious, or highly favorable to the development of such scientific talents as I had, or I probably would not be on this platform today. Perhaps a few words about my first experience with this organization will be of interest.

In 1916, following its financial reorganization, the Westinghouse company was a very large and successful corporation. Many thousands of people were employed by it, and the work of these many thousands was apportioned, directed, and integrated through the wonderful system of organization of the company.

A popular conception is that the organization of a large successful company is like that of a smooth-running machine. Like the cogs, wheels, and levers of the machine, each man in the organization has his own clearly defined tasks and duties, which co-operate and fit in with the tasks and duties of other men so that the whole organization functions to perform that for which it was planned.

However, and in my opinion, fortunately this conception is true in only a very rough and approximate manner. If the organization is to be compared to a machine at all, it must be compared not to a well-tuned-up smooth-running machine, but rather to one with loose play in many places, the parts of which are held together at different points by the most various strategems, but which still lumbers along in spite of a wheel slipping here, and a cylinder missing there.

For, unlike the cogs and wheels of the machine, which can be shaped precisely with close tolerance for their specific functions, the men who make up the organization are completely nonstandard. Everyone is different from every other one, and machine adjustment must be loose to accommodate itself to such variable parts.

This analogy with a machine thus becomes strained, but I shall strain it further by pointing out a quality which is possessed by the recalcitrantly nonstandard human cogs and wheels of the corporate organization but is absent in the precise cogs and wheels of the machine, and which makes the human organization a far more rugged, reliable, dependable, and adaptable organization, than the most perfectly designed inanimate machine could ever be. I have observed this quality frequently and have benefited by it continuously.

This quality of the human cog is his conscious awareness that he is part of the larger organization, and that his particular task has purpose only in relation to the functioning of the larger organization. A carburetor is indifferent to whether its motor is running properly or not.

Give it its proper adjustment, and it will continue to feed fuel to the cylinder regardless of whether the spark plug is firing or not. Not so in the human organization. When a human spark plug misses, the human carburetor alters his function, because he knows that while his set task is to feed fuel, there is no purpose in this if the spark plug is not carrying on his appointed task. Without this quality of humans, no complex organization, however carefully worked out, could ever function.

I must have been a particularly odd-shaped piece when I tried to fit into the Westinghouse organization in 1916, for very early I had reason to be thankful for the necessary looseness of organization. After working in the shops as an apprentice for most of a year, I started "on regular," as an assistant in "high-tension test" a works laboratory, in the electrical section of the research engineering department. C. E. Skinner was head of the department, and Doctor Chubb headed the electrical section. "High-tension test" was not an agreeable place, physically. It was hardly separated from the shop and was grimy, dirty, and very crowded. This laboratory made various tests for the engineering and purchasing departments, including a general oscillographic service. As I remember, my first job was measuring the resistivities of a big pile of sheets of German silver for the purchasing department.

In this laboratory, I came into contact with a number of engineers from various departments. Friendly chats grew into lengthy technical discussions. More engineers came, and presently I was carrying on a lively consulting service from "high-tension test." C. L. Fortescue was a frequent visitor, and he would sit for hours talking and working out with me some of his latest ideas. My pile of German silver strips lay waiting, untouched. The laboratory foreman, H. H. Galleher, a most kindly and lovable gentleman, would pass by and look on. I would be uneasy, because my set task, the measuring of those German silver strips was being neglected, but there was never a complaint nor reprimand from Mr. Galleher. I don't know how he adjusted his time sheets. Perhaps the normal four-hour German silver job slipped in as 10 or 15 hours. But there was enough looseness, so that it could be taken care of. I am sure that when the organization was planned, a consulting service at "high-tension test" was not contemplated, and I am also sure that at no time did any organization chart show such a service going on. But there it was, just the same, thanks to the inevitable looseness of the organization, and thanks also to Mr. Galleher's awareness that the set tasks of the laboratory had significance only in relation to the larger organization of which it was a part.

Doctor Fortescue at that time was a design engineer in the transformer engineering department, according to the organization chart of that department. But in all the time I knew him and while he was officially a design engineer, I do not recall that he designed a single transformer. He had designed many before, but now organization lines bent before his talents. I would guess that much more of his time was spent on matters relating to other departments than the transformer engineering department. Nevertheless the manager of that department, Mr. McConahey, managed somehow to swallow up Doctor Fortescue's time in his report to the salary accounting department, for Doctor Fortescue's salary continued to come through.

R. E. Hellmund was another designer, this time in the motor engineering department, who did very little designing while I knew him. He was very largely instrumental in getting me interested in the lightning-arrester problem, introducing me to A. L. Atherton, and encouraging me in the development of my first ideas in that field. I do not recall, but feel very sure that tests on these ideas were made first, and authorizing orders for these tests were issued later.

Mr. Lamme, with whom I had occasional very inspiring talks, held the position of chief engineer. As such, he had responsibility for all engineering activities of the company. But his health was beginning to fail, and it was impossible for him to attend personally to all the details called for by his position according to the organization chart. Nevertheless, he continued to occupy that position until his death a few years later, giving of himself generously where he could. The job simply adjusted itself to this great man, chart or no chart.

I hope that I have not overstated my case and given the impression that I am arguing that any and all organization is undesirable in any enterprise, however complex. That would be absurd. An enterprise involving many men must have assignment of tasks, duties, and responsibilities to various individuals if the enterprise is to function, and such assignment of duties and responsibilities is what is meant by organization. But what I do say is that it is impossible to define these individual tasks and duties in complete detail and still fit individual men in all their variability. Dependence must be placed on the individual's awareness that his immediate tasks have significance and value only in relation to the larger activity. Dependence must be placed on the individuals' good will toward that larger organization and his desire that that larger organization function well. These last are probably what is meant by good "esprit de corps." Dependence must be placed on these last to complete the definition of tasks to fit the individual's own characteristics and capacities and those of his neighbors.

The fitting into the organization of the odd man, and particularly the odd man with special talents, is not easily done by any detailed planned organizational setup. The individual cases are too variable. But a good "esprit de corps" will take care of such situations, shifting the nonrigid organizational lines to meet the particular situation. The examples I have given show that beneath the frustrations and dissatisfactions which are part of the daily life of every man, a good healthy "esprit de corps" existed at the Westinghouse company.

Ultrashort Electromagnetic Waves
VI—Reception

BERTRAM TREVOR

Mr. Trevor deals with the reception of ultrashort electromagnetic waves over line-of-sight paths under practical conditions. He shows that, when directive antennas are employed, there is an optimum antenna height for which the direct and reflected rays are received in phase producing maximum effect. The concept of excess-noise ratio is developed which evaluates the merit of a receiver in a manner independent of band width, receiver impedance, signal-generator impedance, or frequency. This is the concluding article in a series of six on ultrashort electromagnetic waves. The material contained in these articles was originally presented as a series of lectures before the basic science group of the New York Section at Columbia University. A consolidated reprint will be available (see announcement elsewhere in this issue).

PAUL C. CROMWELL, Chairman, Symposium Committee
(College of Engineering, New York University, New York 53, N. Y.)

IN recent years there has been much progress in the field of reception using ultrashort electromagnetic waves. Unfortunately, it is not feasible at this time to disclose some of the more interesting developments associated with the war effort. Our discussion concerns fundamentals which are applicable to reception in general, and in particular to the higher frequencies which are not reflected by the Kennelly-Heaviside layer, or so called ionosphere.[1-4] No very sharp division can be made between these two regions, since the ionization of the upper atmosphere is so variable with time of day, season, and sun-spot cycle. Strong signals as high as 45 megacycles per second have been received from Europe by way of sky wave reflection.

PROPAGATION

The ultrashort waves to be considered are propagated in much the same way as light. The field at a receiving antenna is the result of the combination of a direct and one or more reflected rays. In the simplest case, there is only one reflected ray from the ground (see Figure 1). The resulting field strength depends upon the relative phase and amplitude of the two components. The phase relation is determined by the path-length difference between the two rays and the phase shift occurring at the reflection point. The relative amplitudes are determined by the absolute value of the reflection coefficient, whereas the absolute amplitudes are determined by the radiated power in the direction considered.

These statements are more concisely given by

$$E = E_o + E_o k\epsilon^{j(\theta+\psi)} = E_o(1 + k\epsilon^{j(\theta+\psi)}) \tag{1}$$

where

E is the resultant field
E_o is the free-space or direct-ray field
$k\epsilon^{j\theta}$ is the ground reflection coefficient
θ is the phase shift at the reflection point
ψ is the phase shift between the direct and reflected rays due to path-length difference

It can be shown that the free-space field from a half-wave dipole is

$$E_o = (7\sqrt{w})/r \text{ volts per meter} \tag{2}$$

for a distance r in meters and a radiated power w in watts.

It has been shown elsewhere[7] that the coefficient of reflection $k\epsilon^{j\theta}$ from a plane surface is given by the following expressions. For horizontally polarized waves

$$k_h\epsilon^{j\theta} = \frac{\sin\phi - \sqrt{\epsilon_o - 1 + \sin^2\phi}}{\sin\phi + \sqrt{\epsilon_o - 1 + \sin^2\phi}} \tag{3}$$

and for vertically polarized waves

$$k_v\epsilon^{j\theta} = \frac{\epsilon_o \sin\phi - \sqrt{\epsilon_o - 1 + \sin^2\phi}}{\epsilon_o \sin\phi + \sqrt{\epsilon_o - 1 + \sin^2\phi}} \tag{4}$$

where

$$\epsilon_o = \epsilon_r - j1.8\times10^{10}g/f \tag{5}$$

ϵ_r = relative dielectric constant of the reflecting plane
g = conductivity of the reflecting plane in mhos per meter
f = frequency
ϕ = the angle between the reflected ray and the reflecting plane

The quantity ϵ_o may be considered the complex dielectric constant taking into account the phase angle introduced by the conductivity of the medium.

The phase shift of the reflected ray due to path length difference can be shown to be

$$\psi = -(4\pi ha)/\lambda r \tag{6}$$

when r is large compared with $a+h$, where h and a are the transmitting and receiving antenna heights and λ the wave length.

Bertram Trevor is assistant research supervisor of the radio reception section of RCA Laboratories, Radio Corporation of America, Riverhead, N. Y.

We now have all of the quantities necessary for the calculation of field intensities over line of sight paths. There is a marked difference between the reflection coefficients of equations 3 and 4, when the medium is dielectric. For vertically polarized waves the reflected ray at grazing incidence has the same amplitude before and after reflection. As the angle ϕ is increased, the coefficient of reflection becomes smaller, while the phase shift θ remains constant at 180 degrees. When ϕ reaches the angle whose cotangent is equal to $\sqrt{\epsilon_r}$, the reflected ray disappears, and a further increase in

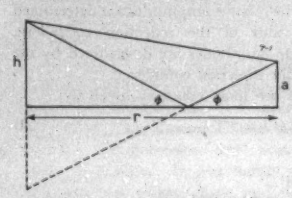


Figure 1. Diagram showing paths of the direct and a single reflected ray

Antenna heights above ground are h and a

ϕ gives a sharply increasing reflected ray with a constant phase shift of zero degrees. For horizontally polarized waves reflecting from a dielectric medium, the phase of the reflected ray remains at 180 degrees, and the amplitude continually drops with increasing ϕ.

Over land paths, it is necessary to plot an actual profile of the circuit to determine the net heights of the transmitting and receiving antennas above the reflecting plane. Normal atmospheric refraction causes a bending of the waves downward, giving a little improvement over an unrefracting atmosphere. This effect is usually taken care of by plotting the profile with 4/3 earth radius in place of unity.

Quite often atmospheric conditions are encountered in which rather sharp discontinuities reflect or refract the waves back to earth, thereby giving increased field intensities at distant points and beyond the horizon. These conditions are more prevalent during the warmer parts of the year.

It is obvious that equation 1 does not take into account diffraction and scattering effects which are always present and become important as the angle ϕ approaches zero.

Equation 1 can be simplified into the approximate equation

$$E = E_0(4\pi ha)/\lambda r = (28\pi\sqrt{w}ha)/r^2\lambda \text{ volts per meter} \qquad (7)$$

for propagation over average ground. The approximation is satisfactory for small values of the angle $(4\pi ha)/\lambda r$ where the sine of the angle and the angle can be considered equal. The approximation is unsatisfactory at grazing incidence where this angle is zero, since diffraction and scattering usually give a field 10 to 30 decibels below the free-space value at grazing incidence.

Let us assume a radio circuit having constant values of r and w with a half-wave dipole antenna at the transmitter and receiver. We are interested primarily in the power delivered to the receiver. Under matched conditions this power is $\left(\frac{E\lambda}{2\pi}\right)^2 \frac{1}{75}$ since the effective length of the dipole is λ/π, or $w_r = E^2\lambda^2/300\pi^2$ watts (8)

Substituting equation 7 for E^2 gives

$$w_r = (2.6ww^2a^2)/r^4 \qquad (9)$$

The received power is seen to be independent of λ so long as we use half-wave dipole antennas at suitable heights above ground to satisfy the approximate equation 7. As the wave length is lowered, the field intensity increases linearly while the effective length of the receiving antenna decreases at the same rate.

If we assume the two antenna heights to be equal, then the received power varies as the fourth power of this height, and this shows the importance of keeping the antennas at a good elevation above ground.

In the ultrashort-wave range, it is very convenient to use directive antennas. Physical considerations usually limit the size of such antennas, and so we will consider one having a constant aperture of S square meters. A field E in free space represents a power of $E^2/120\pi$ watts per square meter. An antenna of aperture S will be capable of absorbing a power of $SE^2/120\pi$ watts. The power gain over a half-wave doublet is then

$$G = \frac{\frac{SE^2}{120\pi}}{\frac{E^2\lambda^2}{300\pi^2}} = 2.5\pi S/\lambda^2 \qquad (10)$$

With antennas of aperture S at each end of the circuit, the received power from equation 9 becomes

$$w_r = \frac{2.6ww^2a^2}{r^4} G^2 = 16.2\pi^2 wS^2 \frac{h^2a^2}{r^4\lambda^4} \qquad (11)$$

By putting $h = a$, we get $w_r = 16.2\pi^2 wS^2(h/r\lambda)^4$ (12)

Equation 12 shows that the received power is proportional to the fourth power of the antenna heights, as well as inversely proportional to the fourth power of the wave length. With fixed-aperture antennas, there is a considerable advantage in going to higher frequencies if the transmitter power w can be maintained constant. It should be noted that constant power is delivered to a receiver by a fixed-aperture antenna in the presence of a constant field intensity, regardless of frequency. This is true even though the power gain of the antenna increases with the square of the frequency, giving a correspondingly narrower directive pattern. It should be remembered that the power gain here used is referred to a half-wave dipole whose effective length is proportional to wave length. The gain in received power with increasing frequency comes about from the increased power radiated in the direction of the receiver by the transmitting antenna directivity, and by virtue of the greater phase delay of the reflected ray causing less cancellation with the direct ray.

Ordinary considerations require the transmitting and receiving antennas to be as high as possible above the intervening terrain. With rather short wave lengths, the phase delay of the reflected ray can reach large values with only moderate heights. Increasing the antenna elevations eventually will bring the reflected and direct rays in phase; at which time maximum signal will be obtained. Further elevation gives a decreasing field until the two components are in phase opposition. Thus the antenna heights must be neither too high nor too low for best results.

SIGNAL-TO-NOISE RATIO

Reception problems in the ultrahigh-frequency range are similar to those in the lower-frequency bands. Since atmospheric disturbances are usually so small as to be neglected, our attention is directed toward obtaining a receiver having as low an internal noise level as possible. Figure 2a shows a receiver input where e represents the induced antenna signal voltage, R_a the antenna radiation resistance, m the step-up voltage ratio of an ideal transformer having no loss or leakage reactance, and R_b a loading to take account of antenna feed-line loss, and transformer inefficiency. Since we are neglecting atmospheric noises, we will substitute a signal generator at room temperature to take the place of R_a and e. With an ideal vacuum tube the thermal agitation noise of resistors R_a and R_b (e_{ta} and e_{tb}, respectively) will supply the only noise appearing at the grid. The ideal vacuum tube will have no electronic input loading and no plate shot noise. Figure 2a and 2b are equivalent diagrams. Thermal noise induced voltage takes the form

$$e_t^2 = 4kT\Delta f R \tag{13}$$

where k is Boltzman's constant (1.37×10^{-23} joules per degree Kelvin), T the ambient temperature in degrees Kelvin, and Δf the over-all effective pass band in question. Then the signal-to-noise ratio at the grid is:

$$S/N = \frac{me\dfrac{R_b}{m^2R_a+R_b}}{\sqrt{4kT\Delta f\dfrac{m^2R_aR_b}{m^2R_a+R_b}}} = \frac{eR_b}{\sqrt{4kT\Delta fR_aR_b(m^2R_a+R_b)}} \tag{14}$$

since the effective resistance at the grid is $m^2R_aR_b \div m^2R_a+R_b$ for noise purposes. As the losses in the input circuits are reduced, R_b becomes very large, making

$$S/N \to \frac{e}{\sqrt{4kT\Delta fR_a}} \tag{15}$$

Under matched conditions $m^2R_a=R_b$, giving

$$S/N = \frac{1}{\sqrt{2}}\times\frac{e}{\sqrt{4kT\Delta fR_a}} \tag{16}$$

which is poorer by the factor $\sqrt{2}$.

Equation 15 shows the performance of an ideal receiver in which the only noise is the thermal agitation noise of the signal source. This optimum value cannot be realized in practice, since there are other noise sources such as

1. Induced input electrode noise in the first tube.
2. Plate shot noise of the first and subsequent tubes referred to the input circuit.

North and Ferris[8] have found the induced grid noise, for tubes with an input control grid adjacent to the oxide-coated cathode, to be equivalent to the thermal noise of a resistor equal to the electronic loading whose temperature is about five times room temperature.

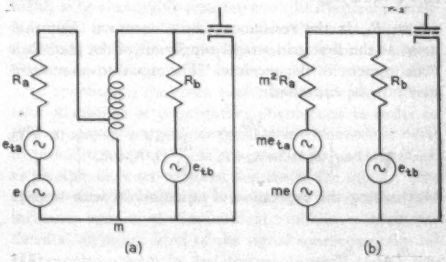


Figure 2

(a). Schematic diagram of receiver input circuit using an ideal vacuum tube

(b). Diagram equivalent to (a) with unity transformation ratio

A high-frequency receiver of good design will have an efficient input transformer, so that the resistor R_b will represent mainly the electronic loading of the input electrode.[2] The generator e_{tb} will then take the form

$$e_{tb} = \sqrt{20kTR_b\Delta f} \tag{17}$$

and equation 14 then becomes

$$S/N = \frac{eR_b}{\sqrt{4kT\Delta fR_aR_b(5m^2R_a+R_b)}} \tag{18}$$

Here the plate shot noise of the first and subsequent tubes has been neglected for simplicity. For this reason it will be seen that, as we make R_b large compared with $5m^2R_a$, the signal-to-noise ratio approaches the ideal value, as shown in equation 15. For a given frequency, the electronic loading R_b is fixed, and so we are tempted to reduce $5m^2R_a$ by reducing m to accomplish the same thing. We soon get into trouble doing this, since a very small value of m provides vanishingly small values of signal and thermal agitation noise at the first grid, leaving nothing but plate shot noise in the receiver output with a very poor signal-to-noise ratio.

In Figure 3 a new noise generator e_{ng} has been inserted in series with the grid to take care of all noises generated

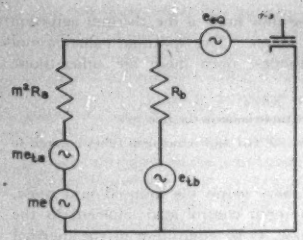


Figure 3. Schematic diagram of receiver input circuit using an actual vacuum tube

subsequent to this electrode in the receiver. This generator may be assumed to take the form

$$e_{eq} = \sqrt{4kT\Delta f R_{eq}} \tag{19}$$

where R_{eq} is the resistance whose terminal agitation noise at the first grid would supply all of the plate shot noise present in the receiver. The signal-to-noise ratio may now be expressed

$$S/N = \frac{eR_b}{\sqrt{4kT\Delta f\left[R_aR_b(5m^2R_a+R_b)+\frac{R_{eq}}{m^2}(m^2R_a+R_b)^2\right]}} \tag{20}$$

Maximizing the expression of equation 20 with respect to m gives

$$m^2 = \frac{R_b}{R_a}\sqrt{\frac{R_{eq}}{R_{eq}+5R_b}} \tag{21}$$

The matched condition corresponds with $m^2 = R_b/R_a$, so that the best signal-to-noise ratio is obtained by making m^2 smaller than the matched value by the factor $\sqrt{R_{eq}/(R_{eq}+5R_b)}$. Thus, if R_{eq} and R_b happen to have about the same values, the impedance step-up of the input transformer should be smaller than the matched condition by a factor of about $\sqrt{1/6}$ in order to achieve best operating conditions. The possible improvement in signal-to-noise ratio over the matched condition will usually be found to be quite small, particularly at the higher frequencies where the electronic loading resistance R_b becomes smaller. In fact, R_b is inversely proportional to the frequency squared for a given tube type.

Since the matched condition gives nearly the best performance in many cases, we can put $m^2 = R_b/R_a$ in equation 20 to give

$$S/N \text{ matched} = \frac{e}{\sqrt{4kT\Delta f\left(6+4\frac{R_{eq}}{R_b}\right)R_a}} \tag{22}$$

Comparing this with equation 16 (the best matched condition) shows the result to be poorer by the factor $\sqrt{1/\left(3+2\frac{R_{eq}}{R_b}\right)}$. Obviously the best S/N ratio will be obtained by making R_{eq} as small as possible and R_b as large as possible, which is, of course, a problem in vacuum-tube design. In addition to this, the receiver input circuits must be made efficient to avoid any unnecessary loss of signal energy there.

Equation 22 express a voltage ratio. By squaring both sides we get the signal-to-noise power ratio which may be expressed as

$$\frac{w_r}{w_n} = \frac{e^2}{4kT\Delta f\left(6+4\frac{R_{eq}}{R_b}\right)R_a} \tag{23}$$

where w_r is the received power referred to under "Propagation," and w_n may be called the noise power input to the receiver referred to the input terminals. From Figure 3 under matched conditions w_r becomes $e^2/4R_a$. Putting this in equation 23 gives

$$w_n = kT\Delta f\left(6+4\frac{R_{eq}}{R_b}\right) \tag{24}$$

Equation 15 shows we cannot improve the signal-to-noise ratio beyond the ideal case where thermal agitation of the signal source supplies all of the noise present in the receiver output. Since all receivers will give poorer results, it is convenient to express the performance of an actual receiver in the following way:

$$\text{Actual measured } S/N = \frac{e}{\sqrt{4kT\Delta f R_a N_e}} \tag{25}$$

where N_e is a dimensionless factor sometimes called the excess-noise ratio. Thus the ratio

$$\frac{S/N \text{ ideal}}{S/N \text{ measured}} = \sqrt{N_e} \tag{26}$$

$$\text{or } \frac{w_n \text{ measured}}{w_n \text{ ideal}} = N_e \tag{27}$$

N_e is then a measure of the excess of the measured noise power over the purely fictitious ideal noise power and is usually expressed in decibels. In the ideal case, there is no power input to the receiver terminals, and so N_e may be considered the ratio of the measured to the ideal-noise powers at the receiver output. These powers then can be referred arbitrarily to the input terminals, as a voltage across any specified resistance.

From equation 22, under matched conditions, the excess-noise ratio is seen to be

$$N_e = 6+4\frac{R_{eq}}{R_b} \tag{28}$$

This equation is valid only when there is no energy-transfer loss from the antenna to the first grid, and when the electronic loading R_b can be considered as a noise generator of the form, $e_{nb} = \sqrt{20kT\Delta f R_b}$.

The concept of using the term, excess-noise ratio, is very convenient, since it completely specifies receiver performance and does not require the specification of band width, receiver input impedance, signal generator impedance, or frequency.

The effective band width Δf, for noise purposes, is the

width of a hypothetical "rectangular" band-pass filter which would pass the same mean-square value of noise current or voltage, with the same transfer ratio at reference frequency (usually mid-band). It is therefore obtained from a plot of the squared response versus frequency curve on linear co-ordinates as follows:

$$\Delta f = \frac{\text{Area under squared response curve in square centimeters}}{\text{Reference frequency squared response in centimeters}} \times \text{abscissa} \frac{\text{cycles per second}}{\text{centimeter}}$$

Going back to the term R_{eq} which was introduced to take care of all noise generated subsequent to the first grid in the receiver, we see that very low stage gains tend to give rather high values of R_{eq}. The reason for this is that plate shot noise from the second and following stages begins to appear in the receiver output. Usually a voltage gain of only two or three per stage is sufficient to avoid this condition.

For a single parallel resonant circuit with tuning capacitance C and shunt resistor R, it can be shown that $RC\Delta f$ is approximately a constant and is independent of the resonant frequency. This relation is also approximately correct (with a slightly different value of the constant) for band-pass filter sections where C is the shunt capacitance and R the terminating impedance. Increasing the value of Δf therefore requires the proportionate reduction of RC. Since the minimum value of C is fixed by tube electrode capacitances, we are forced to reduce R for very wide bands, giving decreasing values of plate load impedances. This gives rise to lower stage gains, since in most cases the gain is proportional to R. This in turn can give higher values of R_{eq} and consequently, poorer noise performance.

In the expressions for signal-to-noise ratio, the factor Δf (over-all effective band width) always appears, since thermal agitation and shot-noise power are proportional to Δf. In the simplest type of receiver the band width is determined by the width of the intermediate frequency amplifier, assuming the circuits after detection are capable of passing the highest rectified side band components. In the ultrahigh-frequency field it is quite common to use a much wider intermediate-frequency amplifier than is required to carry the highest side band components. In this case the circuits after detection determine the over-all band passed for noise purposes, only if there is present a signal carrier having a peak amplitude greater than the peak amplitude of the noise before final detection. Under this condition the noise components may be considered as side bands of the carrier. Thus the circuits after detection accept a radio-frequency band of twice their own band width. If the carrier is not present, noise components beat with each other throughout the whole intermediate-frequency band giving a higher detected noise output. This type of receiver may be said to have a threshold signal level (peak carrier = peak noise) below which the equivalent band width rapidly widens, giving a correspondingly poorer signal-to-noise ratio. Signal measurements with such a receiver should be made with carrier levels above the threshold in order that the factor Δf can be stated concisely.

As contrasted with random noise, we often have to deal with impulse disturbances of which motorcar ignition is the most common source. Here the peak-voltage amplitude of the noise is proportional to the band width, in which the measurement is made, if the band width is sufficient not to cause overlapping of the impulses. With increasing frequency we might expect ignition interference to be less troublesome, because of the poorer efficiency of the spark transmitter. However, measurements[9] show the peak field intensity per cycle of band width to be reasonably constant over the frequency range 40 to 450 megacycles per second. This fact might be explained by improved propagation conditions at higher frequencies as mentioned earlier under "Propagation."

In conclusion, the main problems in reception are to take advantage of propagation phenomena in order to give as strong a signal as possible at the receiver, and to provide a receiver with an excess-noise ratio as small as possible in order to make best use of the signal. The excess-noise ratio is simply a measure of the receiver performance compared with an ideal condition wherein the thermal agitation level of the signal source supplies all of the noise present in the receiver output.

REFERENCES

1. Ultrashort Electromagnetic Waves—I. Electromagnetic Theory, **Ernst Weber.** *Electrical Engineering*, volume 62, March 1943, pages 103–12.

2. Ultrashort Electromagnetic Waves—II. Transmission-Line Theory, **John R. Ragazzini.** *Electrical Engineering*, volume 62, April 1943, pages 159–67.

3. Ultrashort Electromagnetic Waves—III. Generation, **I. E. Mouromtseff.** *Electrical Engineering*, volume 62, May 1943, pages 206–15.

4. Ultrashort Electromagnetic Waves—IV. Guided Propagation, **S. A. Schelkunoff.** *Electrical Engineering*, volume 62, June 1943, pages 235–46.

5. Ultrashort Electromagnetic Waves—V. Radiation (part 1), **Andrew Alford.** *Electrical Engineering*, volume 62, July 1943, pages 303–12.

6. Ultrashort Electromagnetic Waves—V. Radiation (part 2), **Andrew Alford.** *Electrical Engineering*, volume 62, August 1943, pages 338–44.

7. Notes on Propagation of Waves Below 10 Meters in Length. **Bertram Trevor, P. S. Carter.** *Proceedings* Institute of Radio Engineers, volume 21, March 1933, pages 387–426.

8. Fluctuations Induced in Vacuum-Tube Grids at High Frequencies, **D. O. North, W. R. Ferris.** *Proceedings* Institute of Radio Engineers, volume 29, February 1941, pages 49–50.

9. Field Strength of Motorcar Ignition Between 40 and 450 Megacycles, *Proceedings* Institute of Radio Engineers, volume 28, September 1940, pages 409–12.

10. An Analysis of the Signal-to-Noise Ratio of Ultrahigh-Frequency Receivers, **E. W. Herold.** Radio Corporation of America *Review*, volume VI, January 1942, pages 302–21.

11. The Absolute Sensitivity of Radio Receivers, **D. O. North.** Radio Corporation of America *Review* volume VI, January 1942, pages 332–43.

12. Fluctuations in Space-Charge-Limited Currents at Moderately High Frequencies, **B. J. T. Thompson, D. O. North, W. A. Harris.** Radio Corporation of America *Review*, volume IV, January 1940, pages 269–85; volume V, July 1940, pages 106–24, October 1940, pages 244–60, January 1941, pages 371–88, April 1941, pages 505–24; volume VI, July 1941, pages 114–24.

13. Propagation Formulas, **H. O. Peterson.** Radio Corporation of America *Review*, volume IV, October 1939, pages 162–7.

14. The Effect of the Earth's Curvature on Ground-Wave Propagation, **C. R. Burrows, Marion C. Gray.** *Proceedings* Institute of Radio Engineers, volume 29, January, 1941, pages 16–24.

15. Calculation of Ground-Wave Field Intensity over a Finitely Conducting Earth, **K. A. Norton.** *Proceedings* Institute of Radio Engineers, volume 29, December 1941, pages 623–39.

Conductor Redesign Saves Copper

A. A. OSIPOVICH

Wartime contingencies determined the redesign of a major high-voltage transmission line to save 985 tons of newly mined copper for other war purposes. The result is a segmental line carrying five different types of expanded aluminum and copper conductors.

DESIGNING an important high-voltage transmission line is an engineering assignment of major proportions even during so-called "normal times." Under present war conditions such an assignment becomes vastly more complicated. Customary materials are no longer obtainable through normal peacetime supply channels; nor are suitable equipment and qualified manpower readily available for the orderly prosecution of the work.

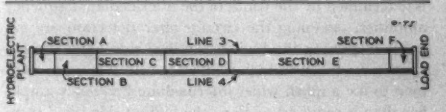
An 83-mile 230-kv transmission line, recently completed and placed in operation in the Pacific North West, transmits power generated at one of the large governmental hydroelectric plants to an important industrial area. The line originally was designed as a conventional double-circuit steel-tower system. It had been located and surveyed to accommodate this type of structure. Because of scarcity of aluminum, the design was based on the use of copper conductors. Load and economy studies led to the use of an expanded-type standard-strength conductor having a minimum outside diameter of 1.08 inches and a copper equivalent area of 500,000 circular mils. Sag–tension characteristics were determined for such conductors, and the steel towers were designed to provide factors of safety, under the National Electric Safety Code, adequate for "Heavy Loading" and the type of country traversed by the line. After these basic design conditions had been determined, the line was sagged-in, and towers were selected as to height, type, and leg extension for each tower location. A contract for their fabrication was awarded, and actual production was started in accordance with established construction and energization schedules. Similarly, conductor specifications had been issued, bids opened, and the *H-H* segmental type of conductor purchased for the full length of the double-circuit line (186 circuit-miles).

Just then the War Production Board decided that, because of great scarcity of newly mined copper, only one circuit of the projected line should be built. Shortly thereafter the board recognized the urgent need for building both 230-kv circuits. Their construction was authorized, however, only on the condition that all expanded 500,000-circular-mil conductors, of whatever type and make, that could be found in unassigned stocks be diverted to use on this line. This was necessary in order that requirements of new copper for fabrication of the *H-H* conductor be reduced to an absolute minimum. Of such conductors, limited quantities of four types were on hand, each type differing from the other in basic material, make, and strength.

As the line and its structures were designed only for standard-strength conductors, the ruling of the War Production Board immediately created a "jigsaw puzzle" type of problem. Time and conditions did not permit resagging the line to suit the most economical characteristics of the conductors found in stock. Nor was it possible to change the strength characteristics of the towers, then in fabrication, to accommodate the higher-strength conductors. Rather, it became necessary to establish such sag–tension relationships for each individual conductor (Table II) as to make it fit, in so far as possible, into the most suitable section of the line considering the structures previously selected, without jeopardizing unduly the originally established factors of safety.

In solving this problem, careful consideration had to be given to the area near the power plant, as fogs have been known to precipitate heavy ice and sleet formations in the area during winter months. It was necessary, therefore, to place the strongest conductors in that area and to grade the line with regard to conductor strength

Table I. Data for Conductors Used, by Sections



Section	Conductor	Location	Right-of-Way Miles	Conductors: Feet Required	Conductors: Pounds Required
A	Alcoa Mallard*	Hydroelectric plant to Tower 22	3.82	123,770	152,732
B	*PDCP 1251-CHSC***	Tower 22 to Tower 59	6.98	226,150	441,174
C	Alcoa Drake†	Tower 59 to Tower 128	13.63	441,600	482,669
D	Anaconda 892-*R3*	Tower 128 to Tower 176	9.56	309,750	484,759
E	General Cable *H-H*	Tower 176 to Tower 401	45.03	1,459,000	2,229,352
F	*PDCP 1251-CHSC*	Tower 401 to Load end	3.75	121,500	237,022

Copper requirement for new conductor as originally ordered ..... 2,100 tons
New copper conductor actually ordered ..... 1,115 tons
Saving of copper ..... 985 tons

* Aluminum Company of America steel-reinforced aluminum Mallard conductor

** Phelps Dodge Copper Products copper and steel-clad copper conductor.

† Aluminum Company of America steel-reinforced aluminum Drake conductor.

A. A. Osipovich is chief of transmission design of the Bonneville Power Administration, Portland, Oreg.; he is a member of the American Society of Mechanical Engineers.

in the direction from the plant to the load end of the line.

Another problem encountered was that of the location of dead-end and transposition towers. In the original design these locations were selected carefully with a view to sectionalizing the line properly for purposes of conductor sagging and to fit the selected transposition scheme. Foundations were designed and steel was ordered in accordance with the nature of the selected locations. In consequence, the points where changes from one type of conductor to another could be made were to a great extent fixed by the original design of the line. In order that maintenance and operation difficulties resulting from so many different conductors in use on the line be reduced to a minimum, it also was decided to install the same type of conductor in both circuits of every section.

A number of trial combinations was necessary before the final plan was selected. According to this plan, five different conductors (Figure 1) illustrated diagrammatically in Table I, are arranged into six sections. The higher-strength aluminum and copper conductors are placed in three sections nearest the plant; these comprise a total of 24½ miles. Standard-strength conductors are arranged in the next two sections having a total length of 54½ miles. The 3¾-mile section nearest the load end utilizes one of the high-strength conductors primarily to use up its available stock and because in this locality the line crosses several major highways.

For all practical purposes, the transposition scheme for the entire line was left as it was originally designed to meet the proper co-ordination requirements. Only two minor changes in line design were necessary. These changes were dictated by the length of the available expanded conductors and the necessity of providing termination points for them. Consequently, design locations of one dead-end tower and one transposition tower had to be interchanged with those of two suspension towers. Simple adjustments in footing design were all that was required to accomplish this shuffle. The final positions of all the towers involved were within a half-mile from their original stations.

In such a manner, the objective of reducing to a minimum the use of new copper, critically needed for other war purposes, was attained through a fairly simple redesign which left the line in no wise disturbed as to its originally laid-out mechanical strength or transposition scheme. New copper was required only for the 90 circuit-miles of the *H-H*-type conductor, instead of the total double-circuit length of the entire line. A saving of approximately 985 tons of newly mined copper was effected, and an important ruling of the War Production Board was fulfilled successfully.

In its present redesigned condition, this line is unique among similar high-voltage transmission lines. It offers excellent opportunities for observation and study of the behavior of its five different types of expanded conductors under as nearly similar conditions as could ever be expected in an installation designed not for experimental but for practical purposes.

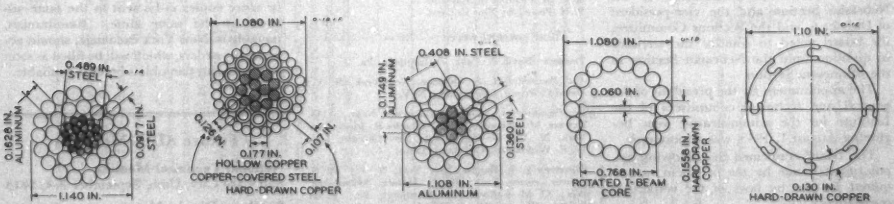
Like so many storm clouds having their silver linings, so, it seems, the war-dictated redesign of the line may prove to be of tangible value in contributing ultimately reliable data for the furthering of modern trends in the design of high-voltage transmission conductors.

Table II. Comparative Data for Conductors Used, Design Conditions

Original—Maximum Working Tension of 10,000 Pounds at One-Half Inch Radial Ice, Eight Pounds Wind and Zero Degrees Fahrenheit (NESC Standard Heavy Loading) for Standard-Strength Expanded 500,000-Circular-Mil Copper Conductor (Minimum Outside Diameter = 1.08 Inches)

Final—Same as Above, Except That Maximum Working Tension to 11,400 Pounds Was Adopted in the Case of Phelps Dodge Conductor of Obtain Approximately Same Sags as for Standard Conductors

	Conductors				
	Section A	Sections B and F	Section C	Section D	Section E
Total area, circular mils	795,000	637,280	795,000	500,300	500,000
Ultimate rated strength pounds	38,400	40,000	31,200	21,250	22,400
Outside diameter, inches	1.140	1.080	1.108	1.080	1.100
Maximum sag for 1,000-ft level span at ½-inch ice, 0 pounds wind, 32 F	34.36	36.64	32.39	37.32	36.83
Tension for above	8,309	10,128	2,176	8,688	8,646
Maximum sag for 1,000-ft level span, 0 pounds wind, 120 F	36.38	38.15	34.42	38.47	36.23
Tension for above	4,292	6,436	4,013	5,155	5,064



A—Steel-reinforced aluminum Mallard conductor used in section A

B—Copper and steel-clad copper conductor used in sections B and F

C—Steel-reinforced aluminum Drake conductor used in section C

D—Hollow copper conductor with rotated I-beam core used in section D

E—Segmental-type hollow copper conductor used in section E

Figure 1. Conductor cross sections

INSTITUTE ACTIVITIES

AIEE Board of Directors Meets

The regular meeting of the board of directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, August 4, 1943.

Minutes were approved of the meeting of the board of directors held June 24, 1943.

Recommendations adopted by the board of examiners July 22, 1943, on applications for election, transfer, and Student enrollment were reported and approved. The following actions were taken on recommendation of the board of examiners: 13 applicants were transferred to the grade of Fellow; 71 applicants were transferred and 36 were elected to the grade of Member; 227 applicants were elected to the grade of Associate; 58 Students were enrolled.

The special committee on pension plans submitted in final form a proposed plan for a retirement system for AIEE employees, which had been prepared by the committee, with the aid of a consulting actuary, by direction of the board of directors. The board adopted the plan and, in accordance with its provisions, appointed as two of the three members of the board of trustees to administer the system, H. S. Osborne (member of the board of directors), and H. H. Barnes, Jr. (Fellow of the Institute, not a member of the board), the third member to be an AIEE employee. The special committee was discharged, with an expression of the board's appreciation of its work.

July disbursements amounting to $32,247.33 were reported by the finance committee and approved by the board.

At its June meeting, the board of directors took action transferring all of North Dakota and all of South Dakota except the western part which is in the Denver Section from the North Central District (number 6) to the Great Lakes District (number 5), making necessary a readjustment of Section territories, as all of the territory affected was included in the Nebraska Section (in District 6). Upon recommendation of the officers of the Nebraska Section and the vice-president of District 6, and the Sections Committee, the board voted to transfer the territory in question from the Nebraska Section to the Minnesota Section.

The appointment by the president of the general and technical committees of the Institute for the administrative year beginning August 1, 1943, was announced.

The board confirmed the following appointments made by the president, as required by the by laws of the respective committees:

Charles LeGeyt Fortescue Fellowship Committee—A. R. Stevenson, Jr., and H. W. Tenney *members* for the three-year term beginning August 1, 1943, and J. M. Gaylord to serve for the unexpired term ending July 31, 1944, of D. F. Niner, resigned.

Lamme Medal Committee—Robin Beach, O. B. Blackwell, and C. M. Laffoon *members* for the three-year term beginning August 1, 1943.

Edison Medal Committee—Carl R. Freehafer, C. A. Powel, and David Sarnoff *members* for the five-year term beginning August 1, 1943, and A. E. Knowlton to serve for the unexpired term ending July 31, 1944, of L. W. W. Morrow, deceased; also W. B. Kouwenhoven *chairman* for the year 1943–44; W. J. Gilson, C. M. Laffoon, and W. Ralph Smith from the board of directors, *members* for the two-year term beginning August 1, 1942.

Section 80 of the bylaws requires that the committee on award of Institute prizes shall consist of the chairmen of certain committees, and of such other committees as the board of directors may designate. The board directed that the chairmen of the communication, electrical machinery, power transmission and distribution, and protective devices committees be appointed as additional members of the committee for the year beginning August 1, 1943.

Representatives of the Institute on other bodies were appointed for the year beginning August 1, 1943. (See list of representatives elsewhere in this issue.) Other representatives appointed were:

Everett S. Lee to the Engineers' Council for Professional Development for the three-year term beginning in October 1943.

G. L. Knight reappointed to the library board of the United Engineering Trustees, Inc., for the four-year term beginning in October 1943.

C. E. Stephens reappointed to the board of trustees of the United Engineering Trustees, Inc., for the four-year term beginning in October 1943.

W. A. Lewis to the research procedure committee of The Engineering Foundation for the one-year term beginning October 1, 1943.

R. T. Henry reappointed a representative on the Standards Council of the American Standards Association for the three-year term beginning January 1, 1944.

H. E. Farrer, H. L. Huber, and E. B. Paxton reappointed alternates on the Standards Council for the calendar year 1944.

Local honorary secretaries of the Institute were reappointed for the two-year term beginning August 1, 1943, as follows:

R. H. Bowles for Brazil.
A. F. Enstrom for Sweden.
A. P. M. Fleming for England.
P. H. Powell for New Zealand.

Those present were:

President—Nevin E. Funk, Philadelphia, Pa.

Past Presidents—H. S. Osborne, New York, N. Y.; David C. Prince, Schenectady, N. Y.

Vice-Presidents—L. A. Bingham, Lincoln, Nebr.; A. G. Dewars, Minneapolis, Minn.; Charles R. Jones, New York, N. Y.; C. W. Ricker, New Orleans, La.; W. E. Wickenden, Cleveland, Ohio.

Directors—T. F. Barton, New York, N. Y.; M. S. Coover, Ames, Iowa; K. L. Hansen, Milwaukee, Wis.; C. M. Laffoon, East Pittsburgh, Pa.; T. G. LeClair, Chicago, Ill.; S. H. Mortensen, Milwaukee, Wis.; W. B. Morton, Philadelphia, Pa.; W. Ralph Smith, Newark, N. J.; R. G. Warner, New Haven, Conn.

National Treasurer—W. I. Slichter, Schenectady, N. Y.

National Secretary—H. H. Henline, New York, N. Y.

Series on Ultrashort Waves to Be Issued as Pamphlet

The series of articles currently being published in *Electrical Engineering* on "Ultrashort Electromagnetic Waves," of which the concluding article appears in this issue, is being reprinted in pamphlet form in response to numerous requests. The six articles were presented initially as lectures before the basic science group of the AIEE New York Section in Pupin Hall, Columbia University, during the winter and spring of 1942–43. Professor Paul C. Cromwell of New York University was chairman of the lecture committee.

The articles as subsequently published in *Electrical Engineering* are:

I—Electromagnetic Theory, Ernst Weber, Polytechnic Institute of Brooklyn (*Mar. '43, pp. 103–12*).

II—Transmission Lines at Ultrahigh Frequencies, John R. Ragazzini, Columbia University (*Apr. '43, pp. 150–57*).

III—Generation, I. E. Mouromtseff, Westinghouse Electric and Manufacturing Company (*May '43, pp. 207–15*).

IV—Guided Propagation, S. A. Schelkunoff, Bell Telephone Laboratories, Inc. (*June '43, pp. 235–40*).

V—Radiation, Andrew Alford, Federal Telephone and Radio Corporation (*July '43, pp. 303–12; August '43, pp. 338–44*).

VI—Reception, Bertram Trevor, Radio Corporation of America Laboratories (*Sept. '43, pp. 405–09*).

The purpose of the lectures, which have been published in essentially the form in which they were delivered, was to present to engineers in a condensed and simplified form the fundamental theory of ultrashort electromagnetic waves. For those interested in studying the basic subject matter in more rigorous and complete form, lists of references accompany each article. In order to make the series available for use in a convenient form, a consolidated 64-page pamphlet reprint bound in a substantial cover is being issued. Copies may be obtained from the AIEE order department, 33 West 39th Street, New York 18, N. Y., at 50 cents each; a reduction of 20 per cent will be allowed on orders of ten or more copies to be sent to the same address at the same time. Remittances, payable in New York exchange, should accompany orders, which will be filled as soon as the reprint pamphlets become available.

Future AIEE Meetings

National Technical Meeting
Salt Lake City, Utah, September 2–4, 1943

Southern District Meeting
Roanoke, Va., November 16–18, 1943

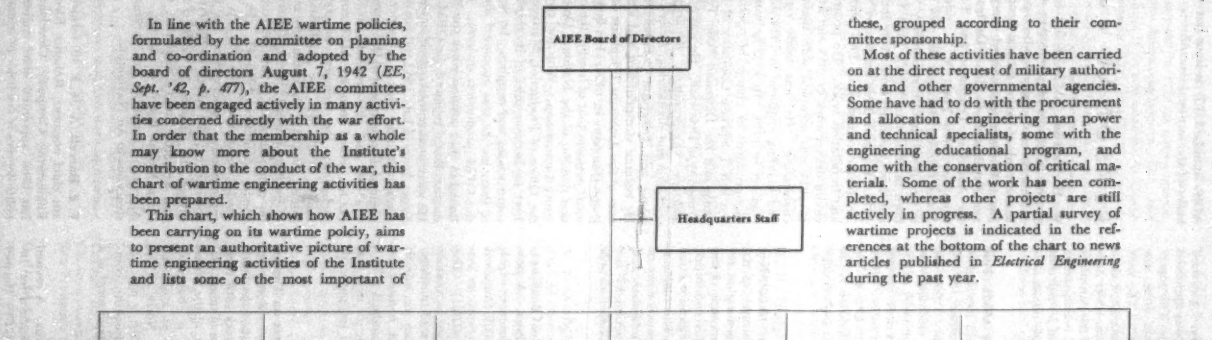
National Technical Meeting
New York, N. Y., January 24–28, 1944

AIEE Wartime Engineering Activities Outlined

In line with the AIEE wartime policies, formulated by the committee on planning and co-ordination and adopted by the board of directors August 7, 1942 (*EE, Sept. '42, p. 477*), the AIEE committees have been engaged actively in many activities concerned directly with the war effort. In order that the membership as a whole may know more about the Institute's contribution to the conduct of the war, this chart of wartime engineering activities has been prepared.

This chart, which shows how AIEE has been carrying on its wartime policiy, aims to present an authoritative picture of wartime engineering activities of the Institute and lists some of the most important of these, grouped according to their committee sponsorship.

Most of these activities have been carried on at the direct request of military authorities and other governmental agencies. Some have had to do with the procurement and allocation of engineering man power and technical specialists, some with the engineering educational program, and some with the conservation of critical materials. Some of the work has been completed, whereas other projects are still actively in progress. A partial survey of wartime projects is indicated in the references at the bottom of the chart to news articles published in *Electrical Engineering* during the past year.


AIEE Board of Directors
Headquarters Staff
Committee on Co-operation With War Agencies[1]
*Procurement of technical specialists for armed services
Consultative committee on engineering—War Manpower Commission
**National Technological Civil Protection Committee
Studies of conservation of materials[2]
Assistance in formulation of reference library for United States Signal Corps[3]
Study of use of silver as a substitute for copper and aluminum in electrical installations[4]
Headquarters Staff
Studies of supply and demand of engineers[5]
National Roster of Scientific and Specialized Personnel[6]
Selection of co-ordinators for defense contracts services
National census of engineering firms
Planning and Co-ordination Committee
General Planning and guidance concerning wartime problems[7]
**Engineering co-operation with South American countries[8]
**Engineers Defense Board (terminated in 1942)
Standards Committee
Wartime emergency standards[9]
Wartime guides and reports for application and operation of electrical apparatus[10]
Electrical apparatus standards[10]
Special standardizing projects[11]
Technical Program Committee
National technical meetings[12]
District technical meetings[13]
Special programs devoted to wartime subjects[14]
Sections Committee and Sections
*Procurement of technical specialists for armed services
Conservation of critical materials[15]
Information on engineering firms and individuals available for war work
Clinics relating to methods of improving production in war plants[16]
Various Technical Committees
‡Preparation of Standards, guides, reports, pertaining to war effort[17]
Acceleration of regular engineering programs in colleges[18]
Aid in providing research facilities and man power

Government Agencies Requesting Assistance on War Projects

Joint Army-Navy Officer Procurement
Corps of Engineers
Signal Corps
Marine Corps
War Production Board
Office of Civilian Defense
United States Office of Education
Provost Marshall General

*Several committees collaborated in this activity.

**Joint organization with other societies.

‡Apparatus Standards, wartime guides, reports on Standards, generally prepared by technical committees, then submitted to the Standards committee for consideration and approval.

1. *Mar. '43, p. 119.*
2. *Jan. '43, p. 41; Apr. '43, p. 181.*
3. *Sept. '42, p. 476.*
4. *Sept. '42, p. 492; Oct. '42, pp. 540, 541; Nov. '42, p. 583; Dec. '42, p. 634; Jan. '43, p. 40; Feb. '43, pp. 81, 82; Mar. '43, p. 136; Apr. '43, p. 185; May '43, p. 223; June '43, p. 277; July '43, p. 322.*
5. *May '43, p. 224.*
6. *Apr. '43, p. 182.*
7. *Aug. '43, pp. 309, 370.*
8. *June '43, p. 296.*
9. *June '43, p. 258; Aug. '43, p. 361.*
10. *June '43, p. 258.*
11. *Mar. '43, p. 114.*
12. *Dec. '42, p. 616; Jan. '43, p. 25; Mar. '43, p. 115; June '43, p. 255; Aug. '43, p. 350.*
13. *Mar. '43, p. 113; May '43, p. 216; June '43, p. 259.*
14. *June '43, p. 255.*
15. *Oct. '42, p. 527.*
16. *Apr. '43, p. 171; May '43, p. 218; June '43, pp. 265, 277.*
17. *Mar. '43, pp. 123, 125; Aug. '43, p. 375.*
18. *Mar. '43, p. 122; Aug. '43, pp. 372, 373.*

Lamme Medal Nominations

Attention is called again to the opportunity open to any Institute member to submit nominations for the 1943 AIEE Lamme Medal. All nominations must be received not later than December 1. For further particulars see *Electrical Engineering*, une 1943, page 266.

The 1942 medal was awarded to Joseph Slepian, associate director of research, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. Addresses delivered at the presentation ceremonies are published in this issue of *Electrical Engineering*, pages 400–04.

SECTION • • • • •

Washington Section Holds Third Annual Outing

Incoming officers were installed and living past chairmen were honored at the third annual outing of the AIEE Washington Section on June 26, 1943, at Palisades Park, Washington, D. C.

Chairman for 1943–44 is A. G. Ennis (M '38) assistant professor of electrical engineering, George Washington University, Washington, D. C.

Presentation of Institute emblems to all past chairmen attending, including F. A. Wolff (M '34) chairman, 1903–04, and retiring chairman G. R. Wilhelm (M '42), was made by Doctor F. B. Silsbee (F '42). He also introduced R. W. Sorensen (F '19) past president of the Institute for 1940–41, who was a visitor to the Section. Special mention was made of the work of Mark Eldredge (F '33) Institute director, in welcoming AIEE members new to Washington during the past year.

Games were played during the early evening, and a musical program, sponsored by the Telephone Glee Clubs, was presented after a picnic supper.

STANDARDS • • •

Rotating Electrical Machinery. On March 29, 1943 the American Standards Association approved a revised edition of the American Standard C50, "Rotating Electrical Machinery." The changes made in this edition, from the 1936 edition, recognize for the most part practices already in effect and to a lesser extent those newly developed. The types of machines covered are as follows: d-c rotating machines; synchronous generators, motors, and synchronous machines in general; synchronous converters; induction motors and machines in general; d-c and a-c fractional-horsepower motors. Copies of the pamphlet may be obtained from AIEE headquarters at $1.25 each, no discount to anyone.

A-C Power Circuit Breakers. A revised edition of AIEE Standard 19 was approved by the Institute May 27, 1943. This supersedes Standard 19, edition of 1938, entitled "Oil Circuit Breakers." The new standard includes the latest accepted data on dielectric tests, provisions for silver contacts, and so forth. Copies of the pamphlet may be obtained from AIEE headquarters at 40 cents each. Discount of 50 per cent to members of AIEE on single copies.

Co-ordination of AIEE and ASME Test Codes. At the June 22, 1943 meeting of the AIEE Standards committee, S. H. Mortensen gave a preliminary report for the Institute's committee on electrical machinery on the work now under way of co-ordinating the AIEE and American Society of Mechanical Engineers test codes, where similar subjects are covered. One of the principal things under consideration is the method of allocation of friction and windage losses for generator units.

Governor Specifications for 10,000-Kw Units. A. C. Monteith, chairman of the AIEE committee on power generation reported at the June 22, 1943 meeting of the Standards committee that his committee is developing governor specifications for 10,000-kw units and above. This material will come before the American Society of Mechanical Engineers in December and will probably be ready for action by the AIEE early in 1944. For further details see this issue, page 427.

Cable Terminal Potheads, Roof Bushings, and Floor and Wall Bushings. A proposal is now in course of development which will result in a revision of AIEE Standard 21, "Apparatus Bushings" (now an approved American Standard, C76.1). The revision will consist of additions to number 21 to cover roof, floor, and wall bushings. Official action by American Standards Association will be requested, revising the scope of the American Standard C76.1 (AIEE number 21) to include the new material. A separate standard for potheads will be developed.

Joint AIEE–ASME Committee on Turbogenerators. The American Society of Mechanical Engineers has asked the Institute to appoint a group to work with their committee on standardization of steam turbines of which K. M. Irwin, of the Philadelphia Electric Company, is chairman. Machines of 10,000 kw and up are to be covered. Chairman J. R. North of the Institute's Standard committee is now arranging with the various Institute committees concerned for the appointment of a mutually satisfactory group.

Industrial Control Apparatus. A revised edition of the American Standard for Industrial Control Apparatus, C19 (former AIEE Standard 15) is now out to letter ballot of the sectional committee.

PERSONAL • • • •

W. H. Harrison (A '20, F '31) brigadier general in charge of production activities of the services of supply, has been promoted to the rank of major general heading the Signal Corps' newly created procurement and distribution division. On leave from the American Telephone and Telegraph Company, New York, N. Y., since 1940, Major General Harrison has now resigned as vice-president of that company. He was born in Brooklyn, N. Y., June 11, 1892, and was graduated from Pratt Institute in 1915. He started his association with the Telephone company in 1909 with repair and installation work. He progressed to circuit design work in 1915 and from 1919 to 1924 was occupied with maintenance engineering. He was made equipment and building engineer in 1924 and plant engineer in 1928. In 1933 he was elected vice-president in charge of operations of the Bell Telephone Company of Pennsylvania and the Diamond State Telephone Company of Delaware. He was appointed assistant vice-president, department of operation and engineering, American Telephone and Telegraph Company in 1937. He became vice-president and chief engineer of the American Telephone and Telegraph Company in 1938. His first government post was that of head of the construction division of the National Defense Advisory Commission. With the creation of the Office of Production Management in 1941 he became chief of its shipbuilding, construction, and supplies. In September of that year he was appointed director of the OPM production division. He continued in that position when the War Production Board replaced the OPM in 1942. He was commissioned colonel in the United States Army in July 1942 and ten days later was raised to the rank of brigadier general. General Harrison was AIEE president in 1937–38 and vice-president in 1935–37. He has served on many AIEE committees including: the technical program committee, 1929–36; the publication committee, 1931–33; the committee on awards of Institute prizes 1931–34; the committee on communication, 1935–36; the Edison Medal committee, 1935–43; the Lamme Medal committee, 1935–38. As Institute representative he served on the following committees: the Alfred Noble Prize Committee, the Charles A. Coffin Fellowship and Research Fund Committee, the John Fritz Medal Board of Award, and the American Committee on Marking of Obstructions to Air Navigation.

F. E. Harrell (A '26, F '40) formerly assistant chief engineer, Reliance Electric and Engineering Company, Cleveland, Ohio, has been appointed chief engineer. He holds degrees of bachelor of science (1924)

and electrical engineer (1929) from Purdue University. Mr. Harrell joined the Reliance company in 1924 as sales engineer. He became design engineer in 1929, chief draftsman in 1929, and engineer in charge of a-c design in 1932. In 1934 he was made assistant chief engineer. For the past ten months he has been director of a new marine division plant of the Reliance company. Mr. Harrell was 1942–43 chairman of the AIEE electrical machinery committee on which he has served since 1926. He is also currently serving on the standards and technical program committees. He is a member of Tau Beta Pi and Eta Kappa Nu.

J. D. Leitch (A '37, M '42) formerly development engineer, Electric Controller and Manufacturing Company, Cleveland, Ohio, has been made chief engineer. He holds the degree of bachelor of science in electrical engineering from the University of Glasgow (1925) and the degrees of master of arts (1933) and doctor of philosophy (1939) in physics from the University of Toronto. From 1927 to 1930 he was lecturer in physics at the University of Toronto (Ont.). He was consultant physicist on radium and X rays for the Ontario Department of Health, Toronto, from 1932 to 1937 in connection with its cancer program. Having spent the years, 1930 to 1932, as Toronto sales representative of the Electric Controller company, he returned to the employ of the company in 1937 as development engineer.

R. S. Judd (A '31, M '35) formerly chief engineer, Southern New England Telephone Company, New Haven, Conn., has been elected vice-president in charge of personnel relations. After a short period with the Russell Tomlinson Electric Company, and its successor, the Rogers Telephone and Electric Company, Danbury, Conn., he was employed in the switchboard department of the Southern New England Telephone Company. In 1912 he became switchboard installation foreman and in 1913 specification writer for telephone central office equipment. He was made traffic engineer in 1920 and appointed chief engineer in 1930.

W. C. Redding (A '20) member of the technical staff, Bell Telephone Laboratories, New York, N. Y., has retired. He was graduated from Worcester Polytechnic Institute with the degree of bachelor of science in 1905 and received the degree of electrical engineer in 1906. From 1906 to 1911 he designed and supervised manufacture of electrical wires and cables for the American Steel and Wire Company, Worcester, Mass. In 1911 he joined the Western Electric Company, New York, N. Y., where he worked on lead-covered telephone cable development. Since 1925 he has continued with this work as a member of the staff of Bell Laboratories.

L. S. Ford (A '09) engineer, outside plant development department, Bell Telephone Laboratories, New York, N. Y., has retired. He holds the degrees of bachelor of science (1905) and electrical engineer (1906) from Worcester Polytechnic Institute. After one year with the Fire Underwriters, New York, N. Y., he joined Albert B. Herrick, Consulting Engineer, New York, N. Y., until 1909. In 1909 he entered the employ of the Western Electric Company, New York, N. Y. His work for that company and since 1925 for Bell Laboratories has been connected with the development of lead-covered cables.

Thomas Martin (A '35) electrician, City of Vancouver, B. C., has retired. Born in Walsall Wood, South Stafford, England, he commenced his career as assistant chief installer, Bell Telephone Company, Winnipeg, Man. From 1907 to 1912 he was journeyman and foreman for Cope and Sons, Vancouver. He started his 30 years of city employment as a journeyman in 1912. In 1928 he was made lighting superintendent and since 1935 he had been chief city electrician.

H. D. Hodgins (A '36, M '42) formerly application engineer, Westinghouse Electric and Manufacturing Company, Spokane, Wash., has been made manager of the company's Spokane office. He has been employed by the Westinghouse company since he graduated from the University of Idaho in 1923. Completing their student training course he became sales engineer for western Nevada and for Westinghouse service on the Grand Coulee Dam. He was transferred to Spokane in 1936.

A. S. Albright (M '37) formerly acting chief of research, Detroit (Mich.) Edison Company, has been made controller of the company. Mr. Albright has been employed by the Edison company since 1912. He was employed in the meter and statistical department until 1916 when he was made assistant superintendent of meters. He became superintendent of meters in 1918. In 1941 he was appointed acting chief of research.

C. S. Lumley (A '23, M '29) formerly coordinating engineer, Roller-Smith Company, Bethlehem, Pa., has been made assistant general manager of the company. Mr. Lumley became associated with the Roller-Smith Company in 1939 as district engineer in the Midwest district, Chicago, Ill. He was transferred to Bethlehem in 1942 as co-ordinating engineer for both the Bethlehem and Allentown, Pa., plants.

F. C. Angle (A '38) formerly manager of the San Francisco (Calif.) district of the Allis-Chalmers Manufacturing Company, has been appointed manager of the entire Pacific region. He received his degree of bachelor of science from Oregon State College in 1923 and joined the Allis-Chalmers company in 1929. He had been San Francisco manager since 1934.

G. D. McCann (A '38) transmission engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., received his engineering degrees from the California Institute of Technology and not from the University of California as was reported in the July issue of *Electrical Engineering*.

K. J. Affanasiev (M '41) formerly engineer for special studies, Pennsylvania Water and Power Company, Baltimore, Md., is on wartime leave of absence. He has taken the position of development engineer in the air-borne instruments laboratory of Columbia University, New York, N. Y.

W. T. Grumbly (A '28, M '36) formerly engineer, Consolidated Edison Company of New York (N. Y.), Inc., is on wartime leave of absence from that company. He is now employed as a field engineer, division of war research, Columbia University, New York, N. Y.

G. G. Hyde (M '39) formerly staff engineer, Consolidated Edison Company of New York (N. Y.), Inc., has joined the firm of McKinsey and Company, New York, N. Y., as consultant in business and plant construction.

A. B. Cooper (M '16, F '33) general manager and vice-president, Ferranti Electric Company, Ltd., Toronto, Ont., has been elected a member of the executive council from Ontario of the Canadian Manufacturers Association.

M. C. Beebe (A '98, F '13) formerly with the Lea Manufacturing Company, Waterbury, Conn., is now chief development engineer, Hartford standard propeller division of the United Aircraft Company, East Hartford, Conn.

Leon Beauchamp (A '03, M '21) vice-president and chief engineer, the Solex Company, Ltd., Montreal, Que., has been elected a regional vice-president of the Illuminating Engineering Society.

Dean Harvey (A '03, M '13) materials engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been elected president of the American Society for Testing Materials.

N. E. Cannady (A '18, M '25) state electrical engineer and inspector, state insurance department, Raleigh, N. C., has been appointed state civilian defense co-ordinator for electrical services.

A. C. Marshall (A '14, F '29) president and general manager of the Detroit (Mich.) Edison Company, has been awarded the honorary degree of doctor of arts in business administration by Wayne University.

G. H. Bucher (M '24) president of the Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa., has been awarded the honorary degree of electrical engineer by Stevens Institute of Technology.

F. B. Jewett (A '03, F '12) vice-president, American Telephone and Telegraph Company, New York, N. Y., has been elected charter member of the board of trustees of Princeton University.

C. F. Kettering (A '04, F '14) vice-president, General Motors Corporation, Dayton, Ohio, has been awarded the honorary degree of doctor of science by Columbia University.

A. D. Hinckley (A '27, M '38) assistant to the dean of the faculty of engineering, Columbia University, New York, N. Y., has been elected a director of the Illuminating Engineering Society.

T. D. Reimers (M '36) formerly division engineer, Consolidated Edison Company of New York (N. Y.), Inc., has been made electrical superintendent of the company's Hudson Avenue station.

H. S. Williams (A '41) assistant engineer, Rural Electrification Administration, St. Louis, Mo., and lieutenant, junior grade, United States Naval Reserve, has been called to active duty.

E. C. Molina (M '22) who retired from Bell Telephone Laboratories, New York, N. Y., in December 1942, is now with the Office of Scientific Research and Development, Washington, D. C.

Morton Sultzer (M '22) formerly 'executive assistant, systems development department, Bell Telephone Laboratories, Inc., New York, N. Y., is now a lieutenant colonel in the United States Army.

J. R. Reed (A '41) sales and field engineer' National Electric Coil Company, has been transferred to Salt Lake City, Utah, where he will be company representative for the territory west of Denver, Colo.

L. W. Robinson (A '25, M '30) of the engineering department, Commonwealth and Southern Corporation, Jackson, Mich., has been elected assistant secretary of the Consumers Power Company, Jackson.

J. P. Lewis (A '32, M '42) electrical engineer, Stamford, division, Connecticut Power Company, has been appointed assistant to the acting manager of the division.

R. M. Gates (M '35) president of the Air Preheater Corporation, New York, N. Y., has been nominated for the presidency of the American Society of Mechanical Engineers.

P. H. Goodell (A '40) formerly manager of the radiant heat division, C. M. Hall Lamp Company, Detroit, Mich., has joined the Trumbull Electric Manufacturing Company of that city.

Ralph Randall (A '35) sales engineer, General Electric Company, Oklahoma City, Okla., has been elected president of the Engineering Club of that city.

OBITUARY • • • •

William F. Grimes (A 19', M '27) captain, United States Navy, died June 26, 1943. Captain Grimes, was born February 21, 1895, in Pasadena, Calif. He was a member of the class of 1917 at the University of Southern California and was awarded the honorary degree of master of science by that university in 1942. During 1917 and 1918 he was attached to the staff of the commander in chief of the United States Fleet, working on maintenance of communication equipment. He was with the Bureau of Standards, Naval Radio Research Laboratory, Washington, D. C., (1918–19). From 1919 to 1924 he was expert radio aid in the Bureau of Engineering, Navy Department, Washington, D. C., and was also civilian in charge of radio design and construction. He engaged in sales and engineering work for the Westinghouse Electric and Manufacturing Company, Los Angeles, Calif., from 1925 to 1929. In 1929 he became control engineer. During this time he was also commander of the Naval Communications Reserve. In 1931 he joined the radio interference department of the Radio and Music Trades Association, Los Angeles, and in 1934 became chief engineer of the association. In 1936 he was made chief engineer of the Radio Interference Engineering Bureau and manager in 1937. Called back to active duty in 1941, he was appointed radio materials officer, 11th Naval District United States Naval Reserve, and later that year district communications officer. He was promoted from lieutenant commander to commander in 1941 and to captain in 1942. He served the Institute as a member of the communication committee from 1936 to 1939; as Los Angeles Section chairman in 1937–38; and as District secretary from 1939 to 1941. He was a member of the Institute of Radio Engineers and the author of numerous technical articles.

Charles Edward Stuart (M '18) president of Stuart, James and Cooke, Inc., New York, N. Y., died June 20, 1943. Born in Alexandria, Va., August 29, 1881, he graduated from the Virginia Military Institute in 1901 with the degree of electrical engineer. From 1902 to 1904 he worked in the apprenticeship department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. He served as sales engineer for the Westinghouse company from 1904 to 1910. Since 1911 he had been president of the engineering firm of Stuart, James and Cooke, Inc. During World War I he had charge of the power and light division of the United States Fuel Administration, established as part of the government's fuel conservation program. As consulting engineer to the Union of Soviet Socialist Republics, from 1926 to 1932, he prepared a report on operating conditions in coal, iron, and copper mines, which became the basis of Russian standards of mine operation. He undertook similar assignments in Great Britain and the United States, as well as in other European countries. He served as executive vice-president of the Export–Import Bank, Washington, D. C., from 1934 to 1936. In the latter year he was sent to Europe by President Roosevelt as a member of a commission of inquiry into co-operative enterprises in ten European countries. Recently he had been an associate member of the Power Commission of the War Industries Board, director of the American–Russian Chamber of Commerce, and a governing member of the National Foreign Trade Council. He was a member of the American Institute of Mining and Metallurgical Engineers and the author of a number of technical and economic articles.

Albert Kingsbury (A '08) president of the Kingsbury Machine Works, Frankford, Pa., died June 28, 1943. Born near Morris, Ill., December 22, 1862, he was graduated from Cornell University with the degree of mechanical engineer in 1889. He received the honorary degrees of doctor of engineering from Worcester Polytechnic Institute in 1933, and doctor of science from the University of New Hampshire in 1935. From 1891 to 1899 he was professor and head of the department of mechanical engineering at New Hampshire college, Durham, and in 1899 became professor of applied mechanics at Worcester (Mass.) Polytechnic Institute. He was employed by the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., from 1903 to 1910. Since then he had served the company in a consulting capacity. In 1917 he founded the Kingsbury Machine Works to manufacture the thrust bearing which he had invented. He had been president of the company since its incorporation in 1924. In 1942 the Army–Navy E was awarded the company for its contributions to naval architecture. Holder of numerous patents, Mr. Kingsbury received the gold medal of the American Society of Mechanical Engineers and the John Scott Medal of the City of Philadelphia in 1931, and the Elliott Cresson Medal of the Franklin Institute in 1923. He was an honorary member of the American Society of Mechanical Engineers and a fellow of the American Academy for the Advancement of Science. He was honored as "a modern pioneer" at the National Association of Manufacturer's celebration of the 150th anniversary of the patent system in 1940.

Ian Walter Grace (A '19) erecting engineer, Cory-Wright and Salmon, Campbells' Bay, Auckland, New Zealand, died June 2, 1943. He was born October 18, 1892, at Wanganui, New Zealand. Joining the Royal British Navy in 1907, he later entered the torpedo department. In 1910 he entered the Royal Naval Torpedo School and was appointed staff instructor in electric light and power at Portsmouth, England, in 1913. From 1913 until he was invalided out of service in 1915, he served as torpedo instructor aboard HMAS *Australia*. During 1915 he was chief electrician to the Dominion Portland Cement Company in New Zealand. He joined the New Zealand Expeditionary Force in 1916 and was given charge of electric power at Featherston Military Camp, England. In 1918 he became armature winder for the Waihi

(New Zealand) Grand Junction Gold Company. From 1919 to 1922 he was electrical engineer for the town board, Martinborough, Wairarapa, New Zealand. From 1923 to 1937 he was a partner in the firm of Dale and Grace, Martinborough. Since 1937 he had been erecting engineer with Cory-Wright and Salmon, Ltd.

Harrison Ivan Mickle (A '31) foreman, electrical department, Ford Instrument Company, Long Island City, N. Y., died July 27, 1943. Mr. Mickle, who was born July 26, 1888, in Hillsdale County, Mich., commenced his career as second engineer in the Electric Light and Water Power Station, Reading, Mich., in 1909. From 1913 to 1915 he did motor repair and general construction work for the Crandall Electrical Contracting Company, Jackson, Mich. He had charge of all electrical maintenance work for the American Fork and Hoe Company, Jackson, from 1915 to 1917. During World War I, 1917 to 1919, he was employed at the Brooklyn (N. Y.) Navy Yard. In 1919 he became foreman of the electrical repair shop of The Maintenance Company, New York, N. Y., and from 1921 to 1924 he had charge of the motor repair work of the Eisenberg General Contracting Company, New York, N. Y. He had been foreman at the Ford company since 1925.

Walter Scott Wyman (A '03, M '14, F '19) president of the New England Public Service Company, Augusta, Maine, died November 15, 1942. He was born May 6 1874, in Oakland, Maine. From 1896 to 1899 he was assistant superintendent of the Maine Water Company, Portland. In 1899 he was elected general manager of the Waterville and Fairfield (Maine) Railway and Light Company. He resigned this position in 1901 to organize the Messalonskee Electric Company, Waterville and Oakland, which became the Central Maine Power Company in 1909. After serving as general manager of this company from 1901 to 1910, he assumed the additional duties of treasurer in the latter year. From 1917 to 1920 he was also general manager of the Adirondack Electric Power Corporation, Glens Falls, N. Y. In 1924 he became president of the Central Maine company and since 1926 he had been president of the New England Public Service Company.

Keith Elias Sharp (A '35) general superintendent and chief engineer, Cimarron Utilities Company, Texhoma, Okla., died May 24, 1943. Born September 8, 1903, at Medford, Okla., he graduated from the University of Kansas with the degree of bachelor of science in electrical engineering in 1926. During 1926 he worked as statistical engineer and substation engineer for the Kansas City (Mo.) Power and Light Company and as design engineer for the Guanajuato (Gto.) Power and Electric Company, Mexico. From 1926 to 1930, as engineer for the Panhandle Power and Light Company, Borger, Tex., he mapped electric, gas, and water distribution systems. In 1930 he joined the Cimarron company as general superintendent and chief engineer. As such, he was in charge of all engineering construction and operation. He was a member of Tau Beta Pi.

Telford MacLennan (A '12) retired engineer, Remuera, Auckland, New Zealand, died June 12, 1943. Born October 8, 1885, at Tapanui, New Zealand, he was graduated from Canterbury College, New Zealand University, with the degree of bachelor of engineering. From 1907 to 1909 he was entered in an apprenticeship course, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa. He was erecting engineer with the Westinghouse company at Chicago, Ill., from 1909 to 1911, and at Winnipeg, Man., during 1912. From 1915 to 1920 he was engineer with the New Zealand government's Hydro-Electric Scheme, Lake Coleridge, Canterbury, New Zealand. In 1921 he became district electrical engineer in the public works department, Hamilton, New Zealand. He retired in 1938.

MEMBERSHIP

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical District. Any member objecting to the election of any of these candidates should so inform the national secretary before September 31, 1943, or November 30, 1943, if the applicant resides outside of the United States or Canada.

To Grade of Member

Birdwell, C. T. (Re-election), Curtiss-Wright Corp., Louisville, Ky.
Brown, H. D. (Re-election), General Elec. Co., Schenectady, N. Y.
Garbett, R. A., Crescent Pub. Serv. Co., Wilmington, Del.
Harmer, L. B. (Re-election), Brit. E. African Govt., Nairobi, B. E. A.
Holland, L. N. (Re-election), Univ. of Michigan, Ann Arbor, Mich.
Marty, E. O., Parsons, Brinckerhoff, Hogan & MacDonald, New York, N. Y.
Rollman, W. H. (Re-election), Chem. Warfare Serv., U. S. War Dept., Pine Bluff, Ark.
Stevens, K. M. (Re-election), So. Calif. Edison Co. Ltd., Alhambra, Calif.
Stivender, E. H., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Walker, G. H., Boeing Aircraft Co., Renton, Wash.
Woodruff, R. T. (Re-election), Aluminum Ore Co., St. Louis, Mo.

To Grade of Associate

United States and Canada

1. North Eastern

Abbiati, O., Radiation Lab., MIT, Cambridge, Mass.
Flock, W. L., Radiation Lab., MIT, Cambridge, Mass.
Hafkemeyer, E. E., Jr., General Elec. Co., Schenectady, N. Y.
Hubbard, M. M., Radiation Lab., MIT, Cambridge, Mass.
Laudel, A., Jr., General Elec. Co., Schenectady, N. Y.
Metzger, H. G., General Elec. Co., Bridgeport, Conn.

2. Middle Eastern

Burke, T. A. (Re-election), Villanova College, Villanova, Pa.
Carl, W. C. (Re-election), Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Ditton, J. A., Jr., Bethlehem Steel Co., Bethlehem, Pa.
Fritz, D. E., Westinghouse Elec. & Mfg. Co., Lima, Ohio.
Glick, W. D., Jr., Lancaster Electronics Lab., Lancaster, Pa.
Irwin, T. K., Line Material Co., Zanesville, Ohio.
Jensen, C. H. (Re-election), Copperweld Steel Co., Glassport, Pa.
Loose, H. A., Truscon Steel Co., Cleveland, Ohio.
McKenna, G. W., Jr., General Elec. Co., Philadelphia, Pa.
McMahon, E. G., Ohio Power Co., Philo, Ohio.
Moore, M. N., Office, Chief of Signal Office, Washington, D. C.
Reifschneider, P. J., Gen. Elec. Co., Philadelphia, Pa.
Shuoy, P. F., North Elec. Mfg. Co., Galion, Ohio.
Stadum, C. B., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Yaffee, P., Naval Ordnance Lab., Washington, D. C.

3. New York City

Blume, W. E. (Re-election), W. E. Blume, Inc., Brooklyn, N. Y.
Metz, A. W., Weston Elec. Inst. Corp., Newark, N. J.
Samuelson, B., U. S. Navy Yard, Brooklyn, N. Y.
Thieme, G. B., Bendix Aviation Corp., Brooklyn, N. Y.
Thompson, G. O., M. W. Kellog Co., New York, N. Y.

4. Southern

Galaher, D., Fla. Power Corp., St. Petersburg, Fla.
Garcia, I. L., Fla. Power Corp., St. Petersburg, Fla.
Huiell, B. V., 1st Lt., USA, Maxwell Field, Montgomery, Ala.
McDonald, J. S., U. S. Navy, New Orleans, La.
McKee, S. E., Picasantville Constructors, Inc., Miami, Fla.
Moyers, W. R., Jr., Giffels & Vallet, Inc., Naval Operating Base, Norfolk, Va.
Shedd, R. R., Westinghouse Elec. & Mfg. Co., Chattanooga, Tenn.
Smith, B., Jr., Aluminum Co. of America, Alcoa, Tenn.
Waugh, W. H. H., Jr., T. V. A., Muscle Shoals, Ala.

5. Great Lakes

Fhret, E. L., Aluminum Ore Co., East St. Louis, Ill.
Johnston, C. G., Northern Indiana Pub. Serv. Co., Plymouth, Ind.
Kohlhepp, R. A. H., Allis-Chalmers Mfg. Co., West Allis, Wis.
Quinn, G. C., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Servis, H., Dumore Co., Racine, Wis.
Snowdon, A. E., Univ. of Illinois, Chicago, Ill.
Willis, C. R., Northern Indiana Pub. Serv. Co., Plymouth, Ind.

7. South West

Jones, S. O., U. S. Engineers, Tulsa, Okla.
Shepherd, R. J., U. S. Engr. Office, Denison, Texas.
Thomas, M. F., U. S. Engr. Office, Denison, Texas.

8. Pacific

Becker, H. W., Mare Island Navy Yard, Mare Island, Calif.
Geering, F. R., Pacific Gas & Elec. Co., Oakland, Calif.
Kotnik, E. F., Consol. Vultee Aircraft Corp., San Diego, Calif.
Johnson, C. E., Southern Calif. Tel Co., Los Angeles, Calif.
Rule, J. S., Pacific Gas & Elec. Co., Oakland, Calif.
Snyder, A. T., Flotation Systems, Inc., Los Angeles, Calif.
Stevens, C. H., Consolidated Aircraft Corp., San Diego, Calif.
Wertheimer, A., Westinghouse Elec. & Mfg. Co., Emeryville, Calif.
Woodbury, H. L., City of Glendale, Glendale, Calif.
Woolley, F. B., U. S. Navy Yard, Mare Island, Calif.

9. North West

Belschner, W. F., Columbia Steel Co., Salt Lake City, Utah.
Hattrup, H. E., Univ. of Idaho, Moscow, Idaho.
Howell, H. H., Boeing Aircraft Co., Seattle, Wash.
Miller, W. B., Seattle-Tacoma Shipbldg. Corp., Tacoma, Wash.

10. Canada

Kersey, L. R. (Re-election), University of British Columbia, Vancouver, B. C., Can.

Elsewhere

Akre Montano, E. O. (Re-election), Mexican Lt. & Pr. Co., Mexico, D. F., Mex.
Brewer, R. C., Admiralty Signal Est., Glossop, Derbyshire, England.
Cadman, T. F., Lt. R.N.V.R., Port of Swansea, South Wales.
Canagarayar, Rajakariar (Re-election), Colombo Mun. Council, Colombo, Ceylon.
Littler, H. A., I.C.I. (Alkali) Ltd., Norwich, England.
Sanchez Zarazua, J. R. (Re-election), Mexican Lt & Pr. Co., Mexico, D. F., Mex.
Saunders, E. D., Jamaica Pub. Serv. Co., Ltd., Kingston, Jamaica, B. W. I.
Williams, H. E., Royal Navy, New Haven, Sussex, England.

Total to grade of Associate
United States and Canada, 60
Elsewhere, 8

Officers and Committees for 1943–44

Officers

President

NEVIN E. FUNK — Philadelphia, Pa.
(Term expires July 31, 1944)

unior Past Presidents

DAVID C. PRINCE — Schenectady, N. Y.
(Term expires July 31, 1944)

HAROLD S. OSBORNE — New York, N. Y.
(Term expires July 31, 1945)

Vice-Presidents

District		
1	K. B. McEACHRON	Pittsfield, Mass.
3	CHARLES R. JONES	New York, N. Y.
5	A. G. DEWARS	Minneapolis, Minn.
7	E. T. MAHOOD	Kansas City, Mo
9	E. W SCHILLING	Bozeman, Mont.
	(Terms expire July 31, 1944)	
2	W. E. WICKENDEN	Cleveland, Ohio
4	C. W RICKER	New Orleans, La.
6	L. A. BINGHAM	Lincoln, Nebr.
8	J. M. GAYLORD	Los Angeles, Calif.
10	W. J. GILSON	Toronto, Ont.
	(Terms expire July 31, 1945)	

Directors

T. F. BARTON — New York, N. Y.
M. S. COOVER — Ames, Iowa
R. G. WARNER — New Haven, Conn.
(Terms expire July 31, 1944)

L. R. GAMBLE — Spokane, Wash.
T. G. LECLAIR — Chicago, Ill.
F. R. MAXWELL, JR. — Pensacola, Fla.
(Terms expire July 31, 1945)

K. L. HANSEN — Milwaukee, Wis.
W. B. MORTON — Philadelphia, Pa.
W. R. SMITH — Newark, N. J.
(Terms expire July 31, 1946)

C. M. LAFFOON — East Pittsburgh, Pa.
C. W. MIER — Dallas, Tex.
S. H. MORTENSEN — Milwaukee, Wis.
(Terms expire July 31, 1947)

National Treasurer

W. I. SLICHTER — New York, N. Y.
(Term expires July 31, 1944)

National Secretary

H. H. HENLINE — New York, N. Y.
(Term expires July 31, 1944)

Local Honorary Secretaries

AUSTRALIA—V. J. F. Brain, Department of Public Works, Bridge Street, Sydney, N.S.W.

BRAZIL—Richard H. Bowles, Sao Paulo Tramway Light and Power Company, Sao Paulo

ENGLAND—A. P. M. Fleming, Metropolitan-Vickers Electric Company, Trafford Park, Manchester

FRANCE—A. S. Garfield, 173 Boulevard Haussmann, Paris, 8E

INDIA, NORTHERN—V. F. Critchley, 17 Bahawalpur Road, Lahore, Punjab

INDIA, SOUTHERN—N. N. Iengar, The Tata Power Co. Ltd., Bombay House, Bruce Street, Fort Bombay

NEW ZEALAND—P. H. Powell, Canterbury College, Christchurch

SWEDEN—A. F. Enstrom, Ingenlorvetenskrapsakademien, Stockholm 5

TRANSVAAL, SOUTH AFRICA—W. Eksdon-Dew, P.O. Box 4563, Johannesburg

General Committees

Executive

Nevin E. Funk, *chairman*, 1000 Chestnut St., Philadelphia 5, Pa.

T. F. Barton	D. C. Prince
C. R. Jones	W. I. Slichter
H. S. Osborne	R. G. Warner

Board of Examiners

H. S. Warren, *chairman*, 420 Lexington Ave., New York, N. Y.

P. H. Adams	A. E. Knowlton
R. H. Barclay	T. G. LeClair
M. C. Beebe	Alexander Maxwell
E. D. Doyle	K. B. McEachron
J. F. Fairman	R. C. Roe
C. W. Fick	H. M. Trueblood
A. L. Harding	K. L. Wilkinson
L. F. Hickernell	Sidney Withington R. J. Wiseman

Code of Principles of Professional Conduct

G. A. Waters, *chairman*, 6400 Plymouth Ave., St. Louis, Mo.

Harry Barker	W. M. Piatt
D. D. Ewing	Walter C. Smith
Dugald C. Jackson	W. E. Wickenden

Constitution and Bylaws

I. Melville Stein, *chairman*, Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia 44, Pa.

Mark Eldredge	C. A. Powel
R. L. Jones	W. I. Slichter

Edison Medal

Appointed by the president for term of five years

A. E. Knowlton	W. B. Kouwenhoven, *chairman*	F. V. Magalhaes
	(Terms expire July 31, 1944)	
K. T. Compton	W. D. Coolidge	J. M. Thomson
	(Terms expire July 31, 1945)	
J. T. Barron	R. E. Doherty	J. V. B. Duer
	(Terms expire July 31, 1946)	
F. D. Newbury	D. C. Prince	W. E. Wickenden
	(Terms expire July 31, 1947)	
C. R. Freehafer	C. A. Powel	David Sarnoff
	(Term expires July 31, 1948)	

Elected by Board of Directors from its own membership for term of two years

T. F. Barton	T. G. LeClair	K. B. McEachron
	(Terms expire July 31, 1944)	
W. J. Gilson	C. M. Lafoon	W. R. Smith
	(Terms expire July 31, 1945)	

Ex officio
Nevin E. Funk, president
W. I. Slichter, national treasurer
H. H. Henline, national secretary
(Terms expire July 31, 1944)

Finance

T. F. Barton, *chairman*, General Electric Company, 570 Lexington Ave., New York 22, N. Y.

C. R. Jones	W. R. Smith

Charles LeGeyt Fortescue Fellowship

W. F. Davidson	J. M. Gaylord
	(Terms expire July 31, 1944)
O. E. Buckley, chairman	Ernst Weber
	(Terms expire July 31, 1945)
A. R. Stevenson, Jr.	H. W. Tenney
	(Terms expire July 31, 1946)

Headquarters

E. C. M. Stahl, *chairman*, Consolidated Edison Co. of New York, Inc., 4 Irving Place, New York 3, N. Y.

T. F. Barton	H. H. Henline

Lamme Medal

P. H. Chase		I. Melville Stein
	S. B. Williams, *chairman*	
	(Terms expire July 31, 1944)	
C. L. Dawes	J. L. Hamilton	K. B. McEachron
	(Terms expire July 31, 1945)	
Robin Beach	O. B. Blackwell	C. M. Lafoon
	(Terms expire July 31, 1946)	

Membership

John H. Pilkington, *chairman*, Consolidated Edison Company of New York, Inc., 4 Irving Place, New York 3, N. Y.

W. S. Hill, *vice-chairman*, General Electric Company, 570 Lexington Ave., New York 22, N. Y.

L. A. Bingham	W. J. Lyman
Tomlinson Fort	L. C. Miller
F. G. Guldi	E. G. D. Paterson
L. F. Howard	J. R. Riley

District vice-chairmen

(To be appointed) (1)	Donald Thomas (6)
E. P. Yerkes (2)	C. V. Waddington (7)
Allan R. Dixon (3)	Ralph A. Hopkins (8)
Stanley Warth (4)	Richard Setterstrom (9)
LeRoy A. Griffith (5)	Frederick Krug (10)

Ex officio
Chairmen of membership committees of all Sections

Planning and Coordination

David C. Prince, *chairman*, General Electric Company, 1 River Road, Schenectady, N. Y.

T. F. Barton	T. G. LeClair
G. W. Bower	J. R. North
F. A. Cowan	H. H. Race
H. H. Henline	I. Melville Stein

Prizes, Award of Institute

F. A. Cowan, *chairman*, American Tel. & Tel. Company, 195 Broadway, New York 7, N. Y.

H. A. Affel		W. A. Lewis
P. L. Alger		J. B. MacNeill
F. E. Harrell	H. E. Wulfing	H. H. Race

Publication

H. H. Race, *chairman*, Research Laboratory, General Electric Company, 1 River Road, Schenectady, N. Y.

C. E. Dean	John Mills
F. M. Farmer	P. H. Pumphrey
H. H. Henline	C. F. Wagner
K. B. McEachron	S. B. Williams

Research

W. A. Lewis, *chairman*, School of Elec. Engg., Cornell University, Ithaca, N. Y.

F. M. Clark		E. L. Moreland
F. M. Farmer		G. W. Penney
R. H. George		F. B. Silsbee
G. T. Harness		R. W. Sorensen
M. J. Kelly		C. G. Suits
F. R. Maxwell, Jr.	V. K. Zworykin	H. W. Tenney

Safety

W. Ralph Smith, *chairman*, 80 Park Place, Room 5329, Newark, N. J.

L. F. Adams	A. C. Muir
A. B. Campbell	Albrecht Naeter
C. F. Dalziel	C. N. Rakestraw
H. P. Dougherty	E. C. Rue
John Grotzinger	Frank Thornton, Jr.
O. S. Hockaday	E. E. Turkington
L. E. A. Kelso	Wesley Weinerth
R. L. Lloyd	H. B. Williams

Sections

G. W. Bower, *chairman*, Public Service Electric & Gas Company, 80 Park Place, Newark, N. J.

O. C. Brill	E. T. Mahood
M. S. Coover	W. B. Morton
C. A. Faust	R. M. Pfalzgraff
Frederick Krug	C. S. Purnell
S. J. Liberger	E. W. Schilling

J. M. Thomson

Ex officio
Chairmen of all Institute Sections

General Committees (continued)

Standards

J. R. North, *chairman*, Commonwealth & Southern Corp., Jackson, Mich.
A. C. Monteith, *vice-chairman*, Westinghouse Elec. & Mfg. Company, East Pittsburgh, Pa.
H. E. Farrer, *secretary*, A.I.E.E., 33 W. 39th Street, New York 18, N. Y.

P. L. Alger	R. L. Jones
R. C. Bergvall	Alex. Maxwell
W. P. Dobson	S. H. Mortensen
C. M. Gilt	E. B. Paxton
R. T. Henry	H. S. Phelps
T. B. Holliday	Gordon Thompson

Ex officio
Chairmen of Working and Coordinating Committees of the Standards Committee
Chairmen of AIEE Technical Committees
Chairmen of AIEE delegates on other standardizing bodies or sole representatives thereon
President, U. S. National Committee of the International Electrotechnical Commission

Student Branches

R. G. Warner, *chairman*, 7 Alden Avenue, New Haven, Conn.

L. A. Bingham		Everett S. Lee
H. L. Davis, Jr.		H. C. Madsen
A. G. Ennis	E. M. Strong	E. W. O'Brien

Ex officio
Student Branch counselors

Technical Program

F. A. Cowan, *chairman*, American Tel. & Tel. Company, 195 Broadway, New York 7, N. Y.
C. S. Rich, *secretary*, AIEE, 33 W. 39th Street, New York 18, N. Y.

P. L. Alger		S. H. Mortensen
H. W. Bibber		C. P. Potter
M. D. Hooven	T. A. Worcester	Frank Thornton, Jr.

Ex officio
Chairmen of all technical committees, the committee on planning and co-ordination, the committee on safety, and the standards committee

Transfers

M. J. McHenry, *chairman*, Hydro-Electric Power Commission, 620 University Ave., Toronto, Ontario

E. A. Crellin		J. W. Lingary
Arthur L. Jones	I. T. Monseth	K. B. McEachron

Technical Committees

Air Transportation

T. B. Holliday, *chairman*, R.R. 7, Box 260, Dayton, Ohio

W. V. Boughton		J. D. Miner, Jr.
Fred Foulon		E. E. Minor
Vernon H. Grant		C. B. Mirick
R. W. Gemmell		D. C. Prince
John Maxian, Jr.	F. O. Wisman	D. R. Shoults

Automatic Stations

F. F. Ambuhl, *chairman*, Toronto Hydro-Electric System, 14 Carlton St., Toronto, Ontario

R. B. Arthur	J. R. Harrington
W. W. Edson	G. S. Lunge
Joseph A. Elzi	Perry Peterson
L. R. Gamble	C. F. Publow
E. E. George	M. E. Reagan
R. M. S. Goo	G. S. Whitlow
B. E. Hagy	C. E. Winegartner

Basic Sciences

R. W. Ager, *chairman*, Cornell University, Ithaca, N. Y.
J. G. Brainerd, *vice-chairman*, Moore School of Elec. Engg., University of Pennsylvania, Philadelphia, Pa.
J. D. Tebo, *secretary*, 463 West Street, New York 14, N. Y

L. A. Bingham		F. C. Lindvall
A. Boyajian		K. W. Miller
H. L. Curtis		Brian O'Brien
L. O. Grondahl		J. A. Parrott
C. R. Hanna		G. W. Penney
H. L. Hazen		H. H. Race
N. S. Hibshman		Walther Richter
J. E. Hobson		M. F. Skinker
M. J. Kelly		F. G. Tappan
W. A. Lewis	Ernst Weber	G. S. Timoshenko

Communication

H. A. Affel, *chairman*, Bell Telephone Laboratories, 463 West St., New York 14, N. Y.

A. L. Albert		H. E. Kent
H. H. Beverage		D. K. Lippincott
J. D. Booth		F. T. Mahood
F. B. Bramhall		L. R. Mapes
R. S. Burnap		J. R. Martin
J. L. Callahan		R. G. McCurdy
D. E. Chambers		C. W. Mier
I. S. Coggeshall		H. H. Nance
J. B. Coleman		H. H. Newell
F. A. Cowan		E. J. O'Connell
John Davidson, Jr.		L. G. Pacent
H. C. Dillingham		J. G. Patterson
D. D. Geiger		Haraden Pratt
E. E. George		John B. Russell
C. G. Grimes		Arthur Bessey Smith
E. W. Hamlin		R. E. Smith
A. P. Hill		Warner T. Smith
S. B. Ingram		H. M. Turner
G. W. Janson	E. P. Yerkes	W. C. White

Domestic and Commercial Applications

W. F. Ogden, *chairman*, 5600 W. Taylor Street, Chicago 44, Ill.

L. F. Adams	V. G. Lippitt
D. K. Blake	L. W. McCullough
M. M. Brandon	H. E. Metz
M. K. Brody	Max Rothpletz
Carl W. Evans	H. P. Seelye
R. W. Fleming	Gordon Thompson
W. R. Harmer	Frank Thornton, Jr.
R. R. Herrmann	R. G. Warner
W. S. Leffler	Wesley Weinerth

Education

Robin Beach, *chairman*, Polytechnic Institute of Brooklyn, 99 Livingston St., Brooklyn, N. Y.

H. W. Bibber		C. A. Powel
G. F. Corcoran		H. C. Powell
O. E. Edison		C. W. Ricker
S. L. Henderson		H. H. Skilling
M. C. Hughes		R. W. Sorensen
E. B. Kurtz		J. G. Tarboux
Everett S. Lee		B. R. Teare, Jr.
W. A. Murray		G. B. Thomas
J. A. Northcott, Jr.		H. N. Walker
R. G. Porter		R. W. Warner

Electrical Machinery

F. E. Harrell, *chairman*, 1088 Ivanhoe Road, Cleveland, Ohio

Sterling Beckwith		C. M. Laffoon
Theodore Braaten		T. C. Lloyd
B. M. Cain		R. C. Moore
J. F. Calvert		T. H. Morgan
J. E. Clem		W. J. Morrill
A. M. deBellis		S. H. Mortensen
G. T. Harness		M. S. Oldacre
C. B. Hathaway		F. D. Phillips
R. A. Heintz		C. P. Potter
J. K. Hodnette		M. L. Schmidt
W. R. Hough		W. C. Sealey
F. P. Kaspar		H. D. Sill
H. H. Kerr		B. Van Ness, Jr.
C. E. Kilbourne		C. G. Veinott
L. A. Kilgore		B. M. Werly

Electric Welding

J. H. Lampe, *chairman*, The University of Connecticut, Storrs, Conn.

C. A. Adams		F. W. Garman
E. M. Callender		K. L. Hansen
L. W. Clark		C. E. Heitman, Jr.
W. E. Crawford		S. M. Humphrey
J. W. Dawson		G. C. Landis
D. D. Ewing		F. W. Maxstadt
G. H. Fett		R. C. McMaster
C. J. Firth	E. H. Vedder	C. L. Pfeiffer

Electrochemistry and Electrometallurgy

C. C. Levy, *chairman*, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

J. V. Alfriend, Jr.		J. E. Housley
F. T. Chesnut		W. C. Kalb
L. H. Fletemeyer		W. B. Kouwenhoven
J. G. Ford		R. M. Pfalzgraff
W. J. Gilson		F. O. Schnure
W. E. Gutzwiller		W. R. Schofield
J. B. Hodtum	N. R. Stansel	M. F. Skinker

Electronics

S. B. Ingram, *chairman*, Bell Telephone Laboratories, 463 West St., New York 14, N. Y.

J. H. Cox		Joseph Slepian
W. G. Dow		Thomas Spooner
T. S. Gray		B. F. Tellkamp
C. C. Herskind		J. T. Thwaites
P. L. Hoover		H. M. Turner
M. E. Reagan		D. C. Ulrey
H. R. Paxson		W. C. White
Walther Richter		C. H. Willis
E. W. Schilling		H. Winograd

Industrial Power Applications

John Grotzinger, *chairman*, Goodyear Tire & Rubber Co., Akron, Ohio

E. L. Bailey		M. J. McHenry
E. T. Carlson		A. C. Muir
L. W. Clark		J. F. Orr
W. G. Dow		W. A. Perry
C. W. Drake		F. O. Schnure
K. K. Falk		Hugh L. Smith
J. S. Gault		Herbert Speight
F. E. Harrell		Jerome J. Taylor
M. R. Horne		E. E. Turkington
Kurt W. John		L. A. Umansky
A. E. Knowlton		R. L. Walsh
E. D. Lilja		W. E. Wickenden
	R. H. Wright	

Land Transportation

A. G. Oehler, *chairman*, Simmons-Boardman Publishing Co., 30 Church St., New York 7, N. Y.
H. C. Griffith, *vice-chairman*, 1617 Pennsylvania Blvd., Philadelphia, Pa.
P. H. Hatch, *secretary*, 514 Siwanoy Place, Pelham Manor, N. Y.

J. C. Aydelott		G. L. Hoard
R. Beeuwkes		J. G. Inglis
Leland W. Birch		Fraser Jeffrey
W. A. Brecht		C. R. Jones
H. F. Brown		L. C. Josepha
C. M. Davis		Paul Lebenbaum
E. B. Fitzgerald		P. A. McGee
E. E. Gardner		T. H. Murphy
W. S. H. Hamilton		J. A. Noertker
	F. W. Willcut	

Light, Production and Application of

W. C. Kalb, *chairman*, National Carbon Co., Carbon Sales Division, Cleveland, Ohio

D. W. Atwater		P. S. Millar
A. G. Dewars		G. T. Minasian
C. L. Dows		R. C. Putnam
S. G. Hibben		Harris Reinhardt
O. W. Holden		C. E. Seymour
H. E. Mahan		E. M. Strong
J. A. McDermott		C. C. Whipple
	I. A. Yost	

Marine Transportation

W. N. Zippler, *chairman*, Gibbs & Cox, Inc., 1 Broadway, New York 4, N. Y.

R. C. Alger		P. B. Harwood
R. A. Beekman		C. J. Henschel
R. D. Bennett		Alex Kennedy, Jr.
H. C. Coleman		Clarence Lynn
P. J. Dumont		F. R. Maxwell, Jr.
J. B. Feder		I. H. Osborne
A. R. Gatewood		Wm. H. Reed
L. M. Goldsmith		E. M. Rothen
H. F. Harvey, Jr.	O. A. Wilde	P. E. Vance

Power Generation

A. C. Monteith, *chairman*, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

F. A. Annett		J. A. Koontz
C. A. Corney		A. J. Krupy
R. P. Crippen		C. M. Laffoon
John Joseph Dougherty		V. M. Marquis
H. A. Dryar		C. W. Mayott
J. H. Foote		G. M. Pollard
A. H. Frampton		Charles R. Reid
R. L. Frisby		Herbert B. Reynolds
Fraser W. Gay		M. J. Steinberg
W. D. Hardaway		H. D. Taylor
Fraser Jeffrey		Robert Treat
	F. D. Troxel	

Technical Committees (continued)

Instruments and Measurements

Chester L. Dawes, *chairman*, Harvard University, Pierce Hall, Cambridge, Mass.
T. S. Gray, *vice-chairman*, Massachusetts Institute of Technology, Cambridge, Mass.
E. I. Green, *secretary*, Bell Telephone Laboratories, 180 Varick St., New York 14, N. Y.

Perry A. Borden — I. F. Kinnard
A. L. Brownlee — W. G. Knickerbocker
L. A. Burckmyer, Jr. — A. E. Knowlton
C. T. Burke — H. C. Koenig
D. T. Canfield — Everett S. Lee
A. G. Dewars — J. T. Lusignan
E. D. Doyle — Paul MacGahan
J. L. Fuller — H. C. Otten
W. N. Goodwin, Jr. — W. E. Pakala
Stanley Green — G. R. Patterson
C. M. Hathaway — E. G. Ratz
N. S. Hibshman — A. R. Rutter
G. B. Hoadley — F. B. Silsbee
F. C. Holtz — Roy M. Smith
H. M. Turner

Power Transmission and Distribution

H. E. Wulfing, *chairman*, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

D. L. Beeman — H. E. Kent
D. K. Blake — A. A. Kroneberg
C. D. Brown — C. M. Laffoon
H. W. Clark — W. W. Lewis
Harold Cole — J. T. Lusignan
C. A. Corney — L. M. Moore
S. B. Crary — E. W. Oesterreich
R. F. Danner — J. S. Parsons
A. E. Davison — W. S. Peterson
G. E. Dean — L. M. Robertson
R. D. Evans — S. J. Rosch
L. R. Gaty — E. V. Sayles
C. M. Gilt — A. E. Silver
I. W. Gross — F. V. Smith
Herman Halperin — Philip Sporn
Edwin Hansson — Stanley Stokes
K. E. Hapgood — O. W. Titus
C. A. Harrington — J. J. Torok
J. B. Hodnum — H. M. Trueblood
E. K. Huntington — C. F. Wagner
J. P. Jollyman — R. J. Wiseman — L. T. Williams

Therapeutics, Applications of Electricity to

C. V. Aggers, *chairman*, Westinghouse Elec. & Mfg. Co., X-Ray Div., 2519 Wilkins Ave., Baltimore 3, Md.

Lloyd L. Call — W. B. Kouwenhoven
W. D. Coolidge — H. C. Rentschler
Roy Kegerreis — C. W. Ricker

Protective Devices

J. B. MacNeill, *chairman*, Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

A. E. Anderson — W. A. Lewis
H. D. Braley — S. C. Leyland
O. E. Charlton — H. J. Lingal
J. E. Clem — F. R. Longley
H. W. Collins — L. R. Ludwig
F. W. Cramer — J. R. McFarlin
William Deans — J. R. North
F. M. Defandorf — H. V. Nye
G. B. Dodds — S. C. Poage
W. S. Edsall — H. H. Rudd
F. R. Ford — W. J. Rudge
L. R. Gamble — H. P. St. Clair
I. W. Gross — A. H. Schirmer
H. W. Haberl — H. P. Sleeper
F. C. Hanker — C. L. Smith
E. L. Harder — F. V. Smith
R. T. Henry — Roy M. Smith
P. A. Jeanne — H. R. Stewart
L. F. Kennedy — H. E. Strang
H. E. Kent — H. R. Summerhayes
A. A. Kroneberg — P. L. Taylor
R. A. Larner — J. J. Tesar
T. G. LeClair — J. M. Towner
J. D. Wood

Special Committee

Registration of Engineers

G. R. Beardsley, *chairman*, New York City Department of Commerce, 60 Broadway, Room 1404, New York 4, N. Y.

A. T. Campbell — T. G. LeClair
Tomlinson Fort — K. B. McEachron
N. B. Hinson — W. H. Stueve
J. G. Wray

Institute Representatives

Alfred Noble Prize Committee, ASCE
Robin Beach

American Association for the Advancement of Science, Council
T. H. Morgan — I. Melville Stein

American Committee on Marking of Obstructions to Air Navigation
G. E. Dean — H. L. Huber

American Coordinating Committee on Corrosion
H. S. Phelps

American Research Committee on Grounding
C. T. Sinclair

American Standards Association, Standards Council
R. T. Henry — J. R. North — H. S. Osborne
Alternates
H. E. Farrer — H. L. Huber — E. B. Paxton

American Standards Association, Board of Directors
J. T. Barron

American Year Book, Advisory Board
H. H. Henline

Committee of Apparatus Makers and Users, NRC
L. F. Adams

Charles A. Coffin Fellowship and Research Fund Committee
Nevin E. Funk

Consultative Committee on Engineering (Advisory to the War Manpower Commission)
John C. Parker

Electrical Standards Committee, ASA
H. L. Huber — V. M. Montsinger — J. R. North
Alternates
H. E. Farrer — E. L. Moreland — E. B. Paxton

Engineering Foundation Board
F. M. Farmer — W. I. Slichter

Engineering Societies Monographs Committee
F. M. Farmer — W. I. Slichter

Engineering Societies Personnel Service, Inc.
H. H. Henline

Engineers' Council for Professional Development
O. W. Eshbach — J. F. Fairman — F. Ellis Johnson

Hoover Medal Board of Award
H. H. Barnes, Jr. — F. M. Farmer — John C. Parker

John Fritz Medal Board of Award
F. M. Farmer — David C. Prince
H. S. Osborne — R. W. Sorensen

Library Board, United Engineering Trustees, Inc.
W. A. Del Mar — G. L. Knight
H. H. Henline — W. I. Slichter

Marston Medal Board of Award
H. B. Gear

National Bureau of Engineering Registration, Advisory Board
C. R. Beardsley

National Fire Protection Association, Electrical Committee
W. Ralph Smith — F. V. Magalhaes, Alternate

National Fire Waste Council
Wills Maclachlan — W. Ralph Smith

(*Continued on next page*)

Geographical District Executive Committees

District	Chairman (Vice-President, AIEE)	Secretary (District Secretary)	Chairman, District Committee on Student Activities
1 North Eastern	K. B. McEachron, General Electric Company, 100 Woodlawn Ave., Pittsfield, Mass.	Victor Siegfried, Worcester Polytechnic Institute, Worcester, Mass.	R. G. Porter, Northeastern University, Boston, Mass.
2 Middle Eastern	W. E. Wickenden, Case School of Applied Science, Cleveland 6, Ohio	H. R. Vaughan, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.	R. C. Gorham, University of Pittsburgh, Pittsburgh, Pa.
3 New York City	G. R. Jones, Westinghouse Elec. & Mfg. Co., 40 Wall St., New York 5, N. Y.	R. L. Webb, Consolidated Edison Co. of New York, Inc., 4 Irving Place, New York 3, N. Y.	D. H. Wright, Pratt Institute, Brooklyn, N. Y.
4 Southern	C. W. Ricker, Tulane University, New Orleans 15, La.	F. E. Johnson, Jr., 317 Baronne St., New Orleans 9, La.	Claudius Lee, Virginia Polytechnic Institute Blacksburg, Va.
5 Great Lakes	A. G. Dewars, Northern States Power Co., 15 S. 5th St., Minneapolis, Minn.	N. C. Pearcy, Public Utility Engg. & Service Corp., 231 S. La Salle St., Chicago, Ill.	H. O. Warner, University of Detroit, Detroit, Mich.
6 North Central	L. A. Bingham, University of Nebraska, Lincoln, Nebr.	Frank C. Howard, Iowa-Nebraska Light & Power Co., Lincoln, Nebr.	(To be appointed)
7 South West	E. T. Mahood, Southwestern Bell Telephone Co., 11th & Oak Sts., Kansas City, Mo.	R. G. Kloeffler, Kansas State College, Manhattan, Kans.	M. A. Thomas, New Mexico State College, State College, N. M.
8 Pacific	J. M. Gaylord, Metropolitan Water District of Southern California, 306 W. 3rd St., Los Angeles, Calif.	Mark A. Sawyer, Box 5300 Metropolitan Station, Los Angeles, Calif.	F. W. Maxstadt, California Institute of Technology, Pasadena 4, Calif.
9 North West	E. W. Schilling, Montana State College, Bozeman, Mont.	W. A. Boyer, Anaconda Copper Mining Co., Butte, Mont.	R. E. Lindblom, University of Washington, Seattle, Wash.
10 Canada	W. J. Gilson, 1244 Duflerin St., Toronto, Ont.	W. Roy Harmer, H.E.P.C. of Ontario, 620 University Ave., Toronto, Ont.	

NOTE: Each District executive committee includes also the chairmen and secretaries of all Sections within the District, and the District vice-chairman of the national membership committee.

Institute Representatives (cont.)

National Research Council, Division of Engineering and Industrial Research

R. W. Sorensen

Quarterly of Applied Mathematics

J. G. Brainerd

Research Procedure Committee, Engineering Foundation

W. A. Lewis

United Engineering Trustees, Inc.

F. M. Farmer — Everett S. Lee — C. E. Stephens

U. S. National Committee, International Commission on Illumination

J. W. Barker — Robin Beach — W. C. Kalb

U. S. National Committee, International Electrotechnical Commission

H. L. Huber — V. M. Montsinger — J. R. North

Alternate

H. E. Farrer — E. L. Moreland — E. B. Paxton

Washington Award Commission

H. B. Gear — L. R. Mapes

World Power Conference, Executive Committee of U. S. National Committee

Nevin E. Funk

General Counsel

Parker & Aaron
20 Exchange Place, New York 5, N. Y.

Student Branches of the Institute

Name and Location	District	Counselor (Member of Faculty)
Akron, Univ. of, Akron, Ohio	2	J. B. Fairburn
Alabama Polytechnic Inst., Auburn	4	W. W. Hill
Alabama, Univ. of, University	4	W. J. Miller
Alberta, Univ. of, Edmonton, Can.	10	
Arizona, Univ. of, Tucson	8	J. C. Clark
Arkansas, Univ. of, Fayetteville	7	W. B. Stelzner
British Columbia, Univ. of, Vancouver, Can.	10	W. B. Coulthard
Brooklyn, Polytechnic Inst. of, Brooklyn, N. Y.	3	A. B. Giordano
Brown Univ., Providence, R. I.	1	E. N. Tompkins
Bucknell Univ., Lewisburg, Pa.	2	K. B. MacKichan
Calif. Inst. of Tech., Pasadena	8	F. W. Maxstadt
Calif., Univ. of, Berkeley	8	P. L. Morton
Carnegie Inst. of Tech., Pittsburgh, Pa.	2	G. R. Patterson
Case School of Applied Science, Cleveland, Ohio	2	P. L. Hoover
Catholic Univ. of America, Washington, D. C.	2	T. J. MacKavanagh
Cincinnati, Univ. of, Cincinnati, Ohio	2	L. R. Culver
Clarkson College of Technology, Potsdam, N. Y.	1	A. R. Powers
Clemson Agricultural College, Clemson, S. C.	4	F. T. Tingley
Colorado State Col. of A. & M. Arts, Fort Collins	6	F. B. Beatty
Colorado, Univ. of, Boulder	6	H. B. Palmer
Columbia Univ., New York, N. Y.	3	J. R. Ragazzini
Connecticut, Univ. of, Storrs	1	G. S. Timoshenko
Cooper Union, New York, N. Y.	3	E. E. Shelton
Cornell Univ., Ithaca, N. Y.	1	E. T. B. Gross
Delaware, Univ. of, Newark, Del.	2	M. G. Young
Denver, Univ. of, Denver, Colo.	6	A. Benson
Detroit, Univ. of, Detroit, Mich.	5	H. O. Warner
Drexel Inst. of Technology, Philadelphia, Pa.	2	E. O. Lange
Duke Univ., Durham, N. C.	4	Otto Meier, Jr.
Florida, Univ. of, Gainesville	4	E. F. Smith
George Washington Univ., Washington, D. C.	2	A. G. Ennis
Georgia School of Technology, Atlanta	4	H. B. Duling
Harvard Univ., Cambridge, Mass.	1	
Idaho, Univ. of, Moscow	9	J. Hugo Johnson
Illinois Inst. of Technology, Chicago	5	E. H. Freeman
Illinois, Univ. of, Urbana	5	E. A. Reid
Iowa State Col., Ames	5	B. S. Willis
Iowa, Univ. of, Iowa City	5	H. R. Reed
Johns Hopkins Univ., Baltimore, Md.	2	F. Hamburger
Kansas State Col., Manhattan	7	J. E. Ward, Jr.
Kansas, Univ. of, Lawrence	7	G. A. Richardson
Kentucky, Univ. of, Lexington	4	E. A. Bureau
Lafayette Col., Easton, Pa.	2	F. W. Smith
Lehigh Univ., Bethlehem, Pa.	2	J. L. Beaver
Louisiana State Univ., Baton Rouge	4	A. K. Ramsey
Louisville, Univ. of, Louisville, Ky.	4	M. G. Northrop
Maine, Univ. of, Orono	1	N. E. Wilson
Manhattan Col., New York, N. Y.	3	R. T. Weil
Marquette Univ., Milwaukee, Wis.	5	E. W. Kane
Maryland, Univ. of, College Park	2	L. J. Hodgins
Mass. Inst. of Technology, Cambridge 39	1	K. L. Wildes
Michigan Col. of Mining & Tech., Houghton	5	Chester Russell
Michigan State Col., East Lansing	5	M. M. Cory
Michigan, Univ. of, Ann Arbor	5	J. S. Gault
Milwaukee School of Engg., Milwaukee, Wis.	5	E. L. Wiedner
Minnesota, Univ. of, Minneapolis	5	J. H. Kuhlmann
Mississippi State Col., State College	4	N. M. McCorkle
Missouri School of Mines & Met., Rolla	7	J. Stuart Johnson
Missouri, Univ. of, Columbia	7	D. Waidelich
Montana State Col., Bozeman	9	E. W. Schilling
Nebraska, Univ. of, Lincoln	6	O. E. Edison
Nevada, Univ. of, Reno	8	S. G. Palmer
Newark Col. of Engineering, Newark, N. J.	3	F. A. Russell
New Hampshire, Univ. of, Durham	1	W. B. Nulsen
New Mexico State Col., State College	7	M. A. Thomas
New Mexico, Univ. of, Albuquerque	7	R. W. Tapy
New York, Col. of the City of, New York	3	Harry Baum
New York Univ., New York	3	P. C. Cromwell
North Carolina State Col., Raleigh	4	L. M. Keever
North Dakota State Col., Fargo	5	H. S. Rush
North Dakota, Univ. of, Grand Forks	5	C. W. Rook
Northeastern Univ., Boston, Mass.	1	R. G. Porter
Northwestern Univ., Evanston, Ill.	5	R. W. Jones
Norwich Univ., Northfield, Vt.	1	D. E. Howes
Notre Dame, Univ. of, Notre Dame, Ind.	5	J. A. Northcott
Ohio Northern Univ., Ada	2	D. S. Pearson
Ohio State Univ., Columbus	2	S. O. Evans
Ohio Univ., Athens	2	W. M. Young
Oklahoma A. & M. College, Stillwater	7	A. Naeter
Oklahoma, Univ. of, Norman	7	R. A. Church
Oregon State Col., Corvallis	9	W. H. Huggins
Pennsylvania State Col., State College	2	P. X. Rice
Pennsylvania, Univ. of, Philadelphia	2	S. R. Warren, Jr.
Pittsburgh, Univ. of, Pittsburgh, Pa.	2	R. C. Gorham
Pratt Institute, Brooklyn, N. Y.	3	D. H. Wright
Princeton Univ., Princeton, N. J.	2	W. C. Johnson
Puerto Rico, Univ. of, Mayaguez, P. R.	3	G. F. Anton
Purdue Univ., Lafayette, Ind.	5	J. H. Karr
Rensselaer Polytechnic Inst., Troy, N. Y.	1	E. D. Broadwell
Rhode Island State Col., Kingston	1	W. J. Mowbray
Rice Inst., Houston, Tex.	7	C. R. Wischmeyer
Rose Polytechnic Inst., Terre Haute, Ind.	5	C. C. Knipmeyer
Rutgers Univ., New Brunswick, N. J.	3	J. L. Potter
Santa Clara, Univ. of, Santa Clara, Calif.	8	W. J. Warren
South Carolina, Univ. of, Columbia	4	W. M. Bauer
South Dakota State College, Brookings	5	W. H. Gamble
South Dakota State School of Mines, Rapid City	6	E. E. Clark
Southern California, Univ. of, Los Angeles, Calif.	8	P. S. Biegler
Southern Methodist Univ., Dallas, Tex.	7	E. H. Flath
Stanford Univ., Stanford University, Calif.	8	H. H. Skilling
Stevens Inst. of Technology, Hoboken, N. J.	3	W. L. Sullivan
Swarthmore Col., Swarthmore, Pa.	2	J. D. McCrumm
Syracuse Univ., Syracuse, N. Y.	1	C. W. Henderson
Tennessee, Univ. of, Knoxville	4	W. O. Leffell
Texas A. & M. Col., College Station	7	N. F. Rode
Texas Technological Col., Lubbock	7	C. V. Bullen
Texas, Univ. of, Austin	7	R. A. Galbraith
Tufts College, Tufts College, Mass.	1	A. H. Howell
Tulane Univ., New Orleans 15, La.	4	J. A. Cronvich
Union Col., Schenectady 5, N. Y.	1	H. W. Bibber
Utah, Univ. of, Salt Lake City	9	L. Dale Harris
Vanderbilt Univ., Nashville, Tenn.	4	S. R. Schealer
Vermont, Univ. of, Burlington	1	E. R. McKee
Villanova Col., Villanova, Pa.	2	H. S. Bueche
Virginia Military Inst., Lexington	4	J. S. Jamison
Virginia Polytechnic Inst., Blacksburg	4	Claudius Lee
Virginia Univ. of, University	4	J. S. Miller
Washington, State College of, Pullman	9	H. F. Lickey
Washington, Univ. of, Seattle	9	R. E. Lindblom
Washington Univ., St. Louis, Mo.	7	D. A. Fischer
West Virginia Univ., Morgantown	2	A. H. Forman
Wisconsin, Univ. of, Madison	5	J. R. Price
Worcester Polytechnic Inst., Worcester, Mass.	1	V. Siegfried
Wyoming, Univ. of, Laramie	6	G. H. Sechrist
Yale Univ., New Haven, Conn.	1	A. G. Conrad
Total Branches	125	

Local Sections of the Institute

Name	District	When Organized	Membership Aug. 1, 1943	Chairman	Secretary	Secretary's Address
Akron	2	Aug. 12, '20	87	R. F. Snyder	H. N. Van Aken	304 Akron Savings & Loan Bldg., Akron, Ohio
Alabama	4	May 22, '29	42	E. R. Coulbourn	C. F. Sittloh	1329—17th St., S. W., Birmingham 7, Ala.
Arizona	8	Mar. 22, '41	37	Malcolm Bridgwater	E. A. Gisel	Central Arizona Light & Power Co., Phoenix, Ariz.
Boston	1	Feb. 13, '03	574	T. Cooper, Jr.	W. I. Middleton	Simplex Wire & Cable Co., Cambridge, Mass.
Central Indiana	5	Jan. 12, '12	133	C. R. Swenson	C. E. Parks	Public Service Co. of Indiana, Inc., Indianapolis, Ind.
Chicago	5	1893	849	F. E. Keith	R. C. Ericson	Northern Indiana Public Service Co., Hammond, Ind.
Cincinnati	2	June 30, '20	151	V. G. Rettig	W. H. Breunig	2411 Upland Place, Cincinnati 6, Ohio
Cleveland	2	Sept. 27, '07	368	P. L. Hoover	V. A. Diggs	Ohio Bell Telephone Co., 750 Huron Rd., Cleveland, Ohio
Columbus	2	Mar. 17, '22	82	S. O. Evans	R. W. Miner	323 No. Ardmore Road., Columbus 9, Ohio
Connecticut	1	Apr. 16, '21	365	E. C. Brown	C. D. Hewitt	P.O. Box 1562, New Haven 6, Conn.
Dayton	2	June 9, '43	122	L. J. Fritz	J. W. Gehrke	Dayton Power & Light Co., 25 No. Main St., Dayton 2, Ohio
Denver	6	May 18, '15	186	W. H. Taylor	L. R. Patterson	Public Service Co. of Colorado, Denver, Colo.
East Tennessee	4	Sept. 2, '36	134	R. M. Ferrill	H. W. Hutchcraft	Tennessee Valley Authority, Chattanooga, Tenn.
Erie	2	Jan. 11, '18	71	H. N. Shaw	W. D. Bearce	4121 Sassafras St., Erie, Pa.
Florida	4	Jan. 28, '31	136	C. F. Titus	P. J. Carlin	Florida Power & Light Co., Miami, Fla.
Fort Wayne	5	Aug. 14, '08	100	C. W. Kronmiller	E. G. Downie	General Electric Co., Fort Wayne, Ind.
Georgia	4	Jan. 14, '04	101	J. E. Mellett	Carl Evans	Electrical South, 1020 Grant Bldg., Atlanta 3, Ga.
Houston	7	Aug. 7, '28	153	H. P. Heafer	Hezzie Clark	P.O. Drawer 2220, Houston 1, Tex.
Iowa	5	June 25, '29	80	W. B. Boast	E. B. Fowler	Northwestern Bell Telephone Co., Des Moines, Iowa
Ithaca	1	Oct. 15, '02	60	A. B. Credle	W. E. Meserve	Cornell University, Ithaca, N. Y.
Kansas City	7	Apr. 14, '16	143	V. P. Hessler	S. H. Pollock	Box 679, Kansas City 10, Mo.
Lehigh Valley	2	Apr. 16, '21	189	R. M. Wyatt	L. Z. Ludorf	Penn. Pwr. & Lt. Co., 135 N. Washington St., Wilkes Barre, Pa.
Los Angeles	8	May 19, '08	548	L. F. Hunt	E. S. Condon	357 South Hill St., Los Angeles 13, Calif.
Louisville	4	Oct. 15, '26	75	L. G. Weiser	M. S. Winstandley	Louisville Gas & Elec. Co., Louisville, Ky.
Lynn	1	Aug. 22, '11	202	W. R. Cox	C. A. Atherton	Champion Lamp Works, 600 Broad St., Lynn, Mass.
Madison	5	Jan. 8, '09	75	L. C. Larson	F. D. Mackie	1202 Elizabeth St., Madison, Wis.
Mansfield	2	Mar. 6, '39	68	R. Felver	C. S. Duckwald	R.D. 5-Rear, 720 Lexington Ave., Mansfield, Ohio
Maryland	2	Dec. 16, '04	349	M. W. Pullen	J. L. Hildebrandt	Consol. Gas Elec. Lt. & Pwr. Co., Monument St. Bldg., Baltimore 3, Md.
Memphis	4	May 22, '30	57	J. F. Fosick	M. G. Sifford	Westinghouse Electric Supply Co., Memphis 1, Tenn.
Mexico	3	June 29, '22	57	G. Robles	Jose Rosas	Mexican Light & Power Co. Ltd., Mexico, D.F. Mexico
Michigan	5	Jan. 13, '11	393	J. W. Bishop	M. M. Cory	Michigan State College, East Lansing, Mich.
Midwestern Canada	10	Oct. 14, '25	26	M. L. Haynes	J. R. Young	1945 Scarth St., Regina, Sask., Can.
Milwaukee	5	Feb. 11, '10	318	R. H. Earle	E. L. McClure	Wisconsin Elec. Pwr. Co., 231 W. Michigan St., Milwaukee 3, Wis.
Minnesota	5	Apr. 7, '02	118	W. H. Gille	L. A. Griffith	Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.
Montana	9	June 24, '31	40	C. R. Davis	W. H. Blankmeyer	Montana Power Co., Butte, Mont.
Montreal	10	Apr. 16, '43	149	Frederick Krug	D. M. Farnham	107 Craig St. West, Room 307, Montreal, Que., Can.
Muscle Shoals	4	Feb. 18, '38	23	R. C. Fuller	Arthur Vaughn	702 Commons, Tuscumbia, Ala.
Nebraska	6	Jan. 21, '25	50	C. P. Kahler	I. M. Ellestad	Northwestern Bell Telephone Co., Omaha, Nebr.
New Mexico–West Texas	7	Mar. 7, '40	48	E. C. Wise	L. R. Hammond, Jr.	2910 Grant Ave., El Paso, Tex.
New Orleans	4	Dec. 8, '33	141	C. P. Knost	F. E. Johnson	317 Baronne St., New Orleans 9, La.
New York	3	Dec. 10, '19	3,586	C. S. Purnell	J. L. Callahan	R.C.A. Communications, Inc., 66 Broad St., New York 4, N. Y.
Niagara Frontier	1	Feb. 10, '25	186	C. E. Gaylord	W. J. Freudenberger	Buffalo Niagara Electric Corp., Buffalo, N. Y.
North Carolina	4	Mar. 21, '29	99	J. J. Strickland	G. H. Bennett	Durham Public Service Co., Durham, N. C.
North Texas	7	May 18, '28	164	H. G. Mathewson	E. H. Flath	Southern Methodist University, Dallas, Tex.
Oklahoma City	7	Feb. 16, '22	90	R. W. Linney	C. L. Jobe	Oklahoma Gas & Electric Co., Oklahoma City 2, Okla.
Philadelphia	2	Feb. 18, '03	863	H. E. Strang	M. L. Lehman	American Tel. & Tel. Co., 530 Bourse Bldg., Philadelphia 2, Pa.
Pittsburgh	2	Oct. 13, '02	657	G. W. Penney	R. C. Gorham	University of Pittsburgh, Pittsburgh, Pa.
Pittsfield	1	Mar. 25, '04	195	J. R. Meador	D. D. MacCarthy	General Electric Co., Pittsfield, Mass.
Portland	9	May 18, '09	177	A. O. Mangold	W. E. Enns	Portland General Elec. Co., Portland, Oreg.
Providence	1	Mar. 12, '20	93	H. P. Turner	G. E. Andrews	40 Bridgham St., Providence, R. I.
Rochester	1	Oct. 9, '14	121	Walter Criley	O. L. Angevine, Jr.	Stromberg-Carlson Co., 100 Carlson Rd., Rochester, 3, N. Y.
St. Louis	7	Jan. 14, '03	295	F. A. Cooper	F. J. McCluskey	James R. Kearney Corp., 4236 Clayton Ave., St. Louis, Mo.
San Diego	8	Jan. 18, '39	56	W. T. Johnson	J. W. Doolittle	Southern California Tel. Co., 914 C St., San Diego 1, Calif.
San Francisco	8	Dec. 23, '04	601	C. E. Baugh	D. I. Anzini	General Electric Co., 804 Russ Bldg., San Francisco 4, Calif.
Schenectady	1	Jan. 26, '03	630	O. C. Rutledge	P. H. Light	General Electric Co., Schenectady, N. Y.
Seattle	9	Jan. 19, '04	249	H. V. Strandberg	G. W. DeSellem	Westinghouse Elec. & Mfg. Co., 3451 E. Marginal Way, Seattle 4, Wash.
Sharon	2	Dec. 11, '25	162	H. S. Gates	F. D. Fielder	1324 Yahres Road, Sharon, Pa.
South Bend	5	Feb. 26, '41	48	L. F. Stauder	C. M. Dunn	General Electric Co., 112 W. Jefferson, South Bend, Ind.
South Carolina	4	Mar. 2, '40	55	F. W. Chapman	W. H. Kendrick	So. Carolina Electric & Gas Co., Columbia, S. C.
South Texas	7	May 23, '30	50	G. E. Schmidt	S. R. Friedsam	Lower Colorado River Authority, Austin, Tex.
Spokane	9	Feb. 14, '13	85	H. E. Mellrud	J. F. Gogins	General Electric Co., 421 W. Riverside Ave., Spokane 8, Wash.
Springfield	1	June 29, '22	51	A. L. Davis	B. N. Durfee	28 Talcott Ave., West Springfield, Mass.
Syracuse	1	Aug. 12, '20	129	M. H. Pratt	J. W. Dice	Westinghouse Elec. & Mfg. Co., 420 N. Geddes St., Syracuse 4, N. Y.
Toledo	2	June 3, '07	88	E. B. Thurston	W. M. Campbell	2145 Central Grove Ave., Toledo, Ohio
Toronto	10	Sept. 30, '03	381	F. C. Barnes	T. C. D. Churchill	76 Adelaide St., West, Toronto, Ont., Can.
Tulsa	7	Oct. 1, '37	79	W. E. Slemmer	P. E. Gentry	Southwestern Bell Tel. Co., 424 So. Detroit Ave., Tulsa 3, Okla.
Urbana	5	Nov. 25, '02	77	G. R. Peirce	A. D. Bailey	University of Illinois, Urbana, Ill.
Utah	9	Mar. 9, '17	85	T. A. Robinson	J. A. McDonald	General Electric Co., P.O. Box 779, Salt Lake City, Utah
Vancouver	10	Aug. 22, '11	98	T. Ingledow	L. B. Stacey	570 Dunsmuir St., Vancouver, B. C., Can.
Virginia	4	May 19, '22	147	C. E. Creecy	A. F. Forbes	Newport News Shipbuilding & Drydock Co., Newport News, Va.
Washington	2	Apr. 9, '03	675	A. G. Ennis	W. F. Dietz	Westinghouse Elec. & Mfg. Co., 323Washington Bldg., Washington 5, D.C.
West Virginia	2	Apr. 9, '40	38	A. M. Rosenblatt	P. M. Barlow	Ravens Park, St. Albans, W. Va.
Wichita	7	Sept. 16, '37	62	G. W. Fisher	R. F. Dice	Kansas Gas & Elec. Co., 200 N. Market St., Wichita 1, Kans.
Worcester	1	Feb. 18, '20	57	J. H. Jewell	R. M. Peirce	American Steel & Wire Co., Electrical Cable Works, Worcester, Mass.
Total Sections	74					

OF CURRENT INTEREST

Report of Planning Commission Proposes Revisions in United States Patent Laws

Several specific means of improving our patent system are proposed in the first report of the National Patent Planning Commission, presented recently to President Roosevelt after an 18-month investigation of the mechanics of the patent law and the use of patents. The commission was appointed in December 1941, directly after the attack on Pearl Harbor, because the President believed that a study needed to "be made of our existing patent laws and procedure . . . by a commission familiar with the problems of science, industry, agriculture, labor, and the consumer." The members of the commission are: Charles F. Kettering, chairman; Chester C. Davis, Francis P. Gaines, Edward F. McGrady, and Owen D. Young; Andrey A. Potter, executive director; Conway P. Coe, executive secretary.

Specific recommendations made in the report are as follows:

1. Protection of the public interest

A. Compulsory recording of contracts.

B. In a suit for infringement, the limiting of a patent owner to a reasonable compensation without prohibiting use of the patented invention when its manufacture is necessary to national defense or public health or safety.

C. Provision for revocation of improperly granted patent.

2. Public register of patents available for licensing.

3. Uniform standard of invention.

A. Establishment of a uniform yardstick for patentability.

B. Re-examination by Patent Office of validity questions.

C. Creation of a court of patent appeals.

4. Establishing definite term of patent grant.

5. Simplification of appellate procedure.

A condensation of the report follows.

. . . The American patent system established by the Constitution giving Congress the "power to promote the progress of science and useful arts," is over 150 years old. . . . The strongest industrial nations have the most effective patent systems, and after a careful study, the commission has reached the conclusion that the American system is the best in the world. However, as with any system of long standing, conditions arise which were not foreseen at the time of its establishment. The American patent system should be adjusted to meet existing conditions without destroying its basic principles.

The basic principles enumerated in the report are that the system has

1. Encouraged and rewarded inventiveness and creativeness, producing new products and processes which have placed the United States far ahead of other countries in scientific and technological endeavor.

2. Stimulated American inventors to originate a major portion of the important industrial and basic inventions of the past 150 years.

3. Facilitated the rapid development and general application of new discoveries in the United States to an extent exceeding that of any other country.

4. Contributed to the achievement of the highest standard of living that any nation has ever enjoyed.

5. Stimulated creation and development of products and processes necessary to arm the Nation and to wage successful war.

6. Contributed to the improvement of the public health and the public safety.

7. Operated to protect the individual and small business concerns during the formulative period of a new enterprise.

PATENTS AND THE WAR EFFORT

Existing laws permit the Government of the United States and its contractors and subcontractors to manufacture and use any invention, patented or unpatented, regardless of the citizenship of the owner, upon the payment of reasonable compensation . . . After consulting with the several Government departments, including the War and the Navy, and affording them an opportunity for the presentation of evidence, the Commission is convinced that the existing laws are adequate to protect the Government during the present national crises.

PROTECTION OF THE PUBLIC INTEREST

The chief beneficiary of our patent system should be the American public . . . Despite these benefits to the general public . . . it is nevertheless true that patents may be and have been abused. The abuse arises not from the patent itself but by virtue of secret, improper, and even illegal agreements. . . . The Commission . . . feels that there should be a compulsory requirement for the recording of the agreements so that they will be available to the public, to governmental agencies, and to congressional committees.

The Commission therefore recommends the passage of legislation compelling the recording in the United States Patent Office of

1. All existing agreements to which one of the parties is a citizen of a country foreign to the United States.

2. All existing agreements, regardless of citizenship of the parties which include any restrictions as to price, quantity of production, geographical areas, or fields of use.

3. All future agreements, regardless of restrictions or citizenship of the parties.

After a study of the needs in this country and the effects in foreign countries of a compulsory licensing system, the Commission has reached the conclusion that it would not be advantageous to incorporate such a general system in our patent laws. However, the Commission is impressed with the need of a degree of compulsion in certain fields, such as national defense, public health, and public safety. . . . The Commission therefore recommends a statutory provision that in a suit for infringement the recovery of a patent owner shall be limited to reasonable compensation without prohibiting the use of the patented invention whenever the court finds that the particular use of the invention in controversy is necessary to the national defense or required by the public health or public safety.

There should be some provision whereby information and facts bearing upon the validity of a patent can be brought to the Patent Office, thereby giving it an opportunity to challenge the validity of any patent in a proceeding begun within six months after its grant. The enabling legislation should specify that the failure to challenge within the period indicated shall not prejudice the rights of any person in a subsequent infringement suit.

EXTENDING THE USE OF PATENTS

The Commission . . . recommends establishment in the Patent Office of a public register upon which would be placed those patents under which the owner would be willing to grant licenses on stated reasonable terms. When an interested party and the owner are unable to agree as to the unstated terms for a license under a patent entered on the register, the Commissioner of Patents shall fix the terms after an opportunity for hearing with right of appeal to the Court of Customs and Patent Appeals.

UNIFORM STANDARD OF INVENTION

The most serious weakness in the present patent system is the lack of a uniform test or standard for determining whether a particular contribution of an inventor merits the award of the patent grant. Revised Statute 4886 provides that a patent may be obtained by

any person who has invented or discovered any new and useful art, machine, manufacture, or composition of matter, or any new and useful improvements thereof . . . upon payment of the fees required by law and other due proceedings had.

The difficulty in applying this statute arises out of the presence of the words "invented" and "discovered." Novelty alone is not sufficient, nor is utility, nor is the final accomplishment. There must also be present some mysterious ingredient connoted in the term "invented." . . . There should be a uniformity in the grant and treatment of patents. The present confusion threatens the usefulness of the whole patent system and calls for an immediate and effective remedy.

. . . A promising improvement would be for Congress, by legislative enactment, to

lay down a reasonable, understandable test by which inventions shall be judged, both from the standpoint of the grant of the patent and the validity of the patent thereafter.

The Commission therefore recommends the enactment of a declaration of policy that patentability shall be determined objectively by the nature of the contribution to the advancement of the art, and not subjectively by the nature of the process by which the invention may have been accomplished.

. . . The validity of a patent is now passed upon initially by any one of almost a hundred district courts in the United States, by 11 different circuit courts of appeals, and occasionally by the Supreme Court. The test of invention should be the same and uniform, whether applied in the Patent Office or in any one of these courts . . .

. . . The Commission therefore recommends that, whenever the validity of a patent is attacked in an infringement suit before a district court, the court shall certify the record to the Patent Office for a report on the validity of the patent. The report of the Patent Office as to the effect of the court record upon the validity of the patent shall be advisory only.

As a final step in remedying the chaotic and confusing conditions surrounding the grant and validity of patents, the Commission considers it imperative to establish a single court of patent appeals which would receive and decide appeals from all of the district courts in patent cases, and whose decisions would be effective not only in a particular circuit but throughout the whole United States . . .

The creation of an entirely new court is not necessary. The Commission notes that the Court of Customs and Patent Appeals has now become a seasoned tribunal whose judges are trained and experienced in patent law. With expanded jurisdiction and additional judges, this court could function as a single patent court of appeals . . .

The Commission therefore recommends the establishment of a single court of patent appeals. It further recommends that the jurisdiction of the existing Court of Customs and Patent Appeals be expanded so as to function as such a court . . .

EARLY TERMINATION OF PATENT GRANT

The term of a United States patent is 17 years from the date of its grant. The expiration date of the patent is of special interest to the public, since it is then that the subject matter of the patent passes into the public domain. It is most desirable and in the public interest that the patent should be issued as promptly as possible after the application is filed. There are numerous ways in which the prosecution of an application can be deliberately delayed and kept pending in the Patent Office for an indefinite time—and the expiration of the term of the patent thus correspondingly deferred . . .

A proposal of long standing is that the patent monopoly shall not endure more than 20 years from the date of its filing in the Patent Office . . . A period of three years has been recognized as a reasonable period for prosecuting an application to allowance. There would be no change in the present 17-year period of a patent in those cases in which the prosecution did not consume more than three years. Any delays beyond that period, however, would ordinarily subtract from the duration of the patent . . . It is recognized that it would be unfair to penalize some applicants by the operation of such a law because a case encountered unavoidable delays or even delays for which the Patent Office was wholly responsible. Therefore there should be some provision for the restoration by the Commissioner of Patents of not more than two years to the life of a patent when the delay has been due to causes beyond the control of the applicant.

The Commission therefore recommends the enactment of a 20-year bill in substantially the same form as presented in H. R. 3211 to the 77th Congress.

SIMPLIFICATION OF APPELLATE PROCEDURE

When an application for patent is finally refused by the Patent Office, the inventor . . . has the option of either appealing to the Court of Customs and Patent Appeals, or filing a bill in equity for review in a United States district court . . .

The existence of these two parallel remedies is largely the result of historical accident and does not appear to be justified or required by any fundamental considerations . . .

The Commission recommends that in ex parte cases the jurisdiction of the Court of Customs and Patent Appeals to review the denial by the Patent Office of an application for patent should be made exclusive, and that the present concurrent jurisdiction of the district courts should be abolished. Sections 4911 and 4915 of the Revised Statutes should be amended accordingly.

SCOPE OF INVESTIGATION

The Commission has reviewed and considered various publications and compilations bearing upon the subject of its inquiry. Among these are

(a). The records of various congressional hearings.

(b). The reports of previous governmental commissions and investigating bodies.

(c). Reports, where available, of investigations made by or on behalf of industrial organizations.

(d). Numerous published papers and contemporaneous articles in trade journals, law journals, and popular periodicals.

Suggestions from individuals and organizations were submitted to the Commission in written communications and at conferences arranged by invitation of the Commission. Proposals and suggestions in great volume were received from widely scattered sources such as

(a). Representatives of Government departments.

(b). Manufacturers' associations, scientific and engineering societies, bar associations, and research institutes.

(c). Individuals, including lawyers, inventors, scientists, engineers, and manufacturers.

FUTURE REPORTS

The present report is confined generally to the mechanics of the patent law and the use of patents. The Commission is now engaged in a study of the policies involved in connection with inventions made by Government employees and by agents and contractors of the Government and with the control and use of patents owned by the Federal Government.

The Commission is also conducting a study in fulfillment of the final directive of the Executive order, i. e.

what methods and plans might be developed to promote inventions and discoveries which will increase commerce, provide employment, and fully utilize expanded defense industrial facilities during normal times.

The results of these studies will be the subject of future reports by the Commission.

Bureau of Standards Improves Standard Frequency Broadcast

The standard frequency broadcast service of the National Bureau of Standards radio station WWV, at Beltsville, Md., near Washington, D. C., has been improved and extended, a new transmitting station built, ten-kilowatt radio transmitters installed, and additional frequencies and voice announcements added, according to a recent announcement. The services include:

1. Standard radio frequencies.
2. Standard time intervals accurately synchronized with basic time signals.
3. Standard audio frequencies.
4. Standard musical pitch, 440 cycles per second, corresponding to A above middle C.

The standard frequency broadcast service makes widely available the national standard of frequency which is of value in scientific and other measurements requiring an accurate frequency. Any desired frequency may be measured in terms of any one of the standard frequencies, either audio or radio. This may be done by the aid of harmonics and beats, with one or more auxiliary oscillators.

The service is continuous at all times day and night. The standard radio frequencies are:

5 megacycles (= 5,000 kilocycles = 5,000,000 cycles) per second, broadcast continuously.

10 megacycles (= 10,000 kilocycles = 10,000,000 cycles) per second, broadcast continuously.

15 megacycles (= 15,000 kilocycles = 15,000,000 cycles) per second, broadcast continuously in the daytime only (that is, day at Washington, D. C.).

All the radio frequencies carry two audio frequencies at the same time, 440 cycles per second and 4,000 cycles per second; the former is the standard musical pitch, and the latter is a useful standard audio frequency. In addition there is a pulse every second, heard as a faint tick each second when one is listening to the broadcast. The pulses last 0.005 second; they may be

used for accurate time signals, and their one-second spacing provides an accurate time interval for purposes of physical measurements.

The audio frequencies are interrupted precisely on the hour and each five minutes thereafter; after an interval of precisely one minute they are resumed. This one-minute interval is provided in order to give the station announcement and to afford an interval for the checking of radio-frequency measurements free from the presence of audio frequencies. The announcement is the station call letters (WWV) in telegraphic code except at the hour and half-hour when the announcement is given by voice.

The accuracy of all the frequencies, radio and audio, as transmitted, is better than a part in 10,000,000. Transmission effects in the medium (Doppler effect, and so forth) may result in slight fluctuations in the audio frequencies as received at a particular place; the average frequency received, however, is as accurate as that transmitted. The time interval marked by the pulse every second is accurate to 0.00001 second. The one-minute, four-minute, and five-minute intervals, synchronized with the seconds pulses and marked by the beginning and ending of the periods when the audio frequencies are off, are accurate to a part in 10,000,000. The beginnings of the periods when the audio frequencies are off are so synchronized with the basic time service of the United States Naval Observatory that they mark accurately the hour and the successive five-minute periods.

Of the radio frequencies on the air at a given time, the lowest provides service to short distances and the highest to great distances. For example, during a winter day good service is given on 5 megacycles at distances from 0 to 1,000 miles, 10 megacycles from about 600 to 3,000 miles, and 15 megacycles from about 1,000 to 6,000 miles. Except for a certain period at night, within a few hundred miles of the station, reliable reception is possible, in general, at all times throughout the United States and the North Atlantic Ocean, and fair reception over most of the world.

Information on how to receive and utilize the service is given in the bureau's letter circular, "Methods of Using Standard Frequency Broadcasts by Radio," obtainable on request. The bureau welcomes reports of difficulties, methods of use, or special applications of the service. Correspondence should be addressed to National Bureau of Standards, Washington, D. C.

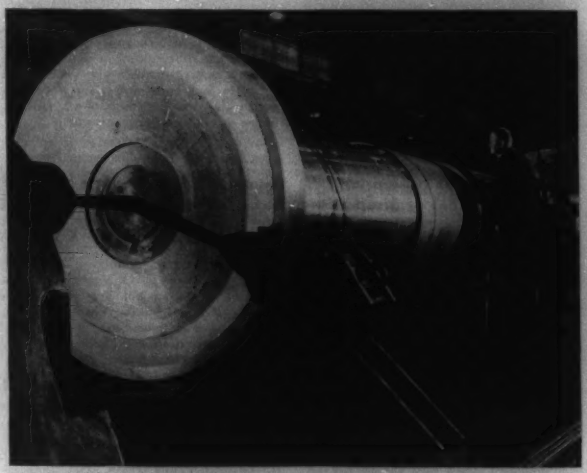
October 3–9 Designated Fire Prevention Week

Fire Prevention Week will be observed October 3–9, 1943, by proclamation of President Roosevelt and the governors of the 48 states. Fire losses are on the increase, and fires are reducing our war production almost $1,000,000 a day and destroying materials needed in the war effort.

During the year 1942 there occurred in the United States, Canada, and Alaska a total of 86 fires, each of which involved a loss of $250,000 or more—an increase of 38 fires over the number reported for 1941. Thirty of these fires caused individual losses of $500,000 or more, including seven which resulted in losses of $1,000,000 or more each. The largest fire loss of the year was the destruction of the liner Normandie in New York, N. Y., February 9, 1942. Depending on the success of salvage operations, the loss from this fire may reach $53,000,000. A total of 515 lives were lost in these fires, 492 of them being accounted for by the Coconut Grove night club fire of November 28. This is in contrast to a total of fifty lives lost in the corresponding fires of 1941.

During 1942 it is estimated that at least 10,000 lives have been lost as a result of fires. Farm fire losses took a toll of over $80,000,000 in property and 3,500 lives. One quarter of the 1941 fires were in manufacturing occupancies with a loss of $73,000,000. Such losses during wartime, when food and supplies are badly needed for us and our Allies and all our manpower and materials are required for a supreme war effort, should spur on all public and private organizations to unite in a campaign during Fire Prevention Week and throughout the year for the removal of all fire hazards which threaten our war production program.

Power "Spool" for Grand Coulee Generator



This 75-ton precision-finished solid steel "spool" being machined at Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., will transmit the force required to drive one of the generators capable of producing 108,000 kw at Grand Coulee Dam. The rotating part of the generator will be mounted on this four-foot-diameter shaft which will couple to a hydroturbine for converting the energy of the water to electric power. Four of the nine waterwheel generators ordered for this hydroelectric project already have been delivered

WAR PROGRAM • •

Construction Started on Motors for Stratosphere Wind Tunnel

Construction of two 20,000-horsepower electric motors for the United States Army's new stratosphere wind tunnel at Wright Field, Dayton, Ohio, has been started recently by Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. The driving units are designed to propel a greater than 600-mile-an-hour gale of refrigerated air into the test chamber where model planes or scale models of aircraft parts will be suspended.

The new tunnel will be a rectangle of metal pipes 600 feet long and varying in diameter from 10 to 40 feet. It will supersede the two-year-old 400-mile-an-hour tunnel now in use and will enable the testing of the high-altitude performance of faster and more deadly fighting planes. The test chamber will duplicate the conditions encountered by pilots and planes in the lower stratosphere, maintaining a constant temperature of 67 degrees below zero and an air pressure less than one fifth as great as it is at sea level.

The two motors will be mounted at adjacent corners of the tunnel, and each will

be connected to its propeller by a 40-foot shaft piercing the tunnel wall. More than 4,000,000 cubic feet of air per minute will be driven through the tunnel by the two counter-rotating propellers mounted hub to hub in the 19-foot section of the pipes. The motors will have a top speed of 465 rpm and can be slowed down to 50 rpm, reducing the air velocity to that of a moderately stiff wind.

Industry to Be Canvassed for 15,000,000 Tons of Scrap

Estimates from the Business Press Industrial Scrap Committee indicate the need for 15,000,000 tons of iron and steel scrap during the coming six months for war production. Since private sources of scrap have been virtually exhausted, the bulk of this must come from industry.

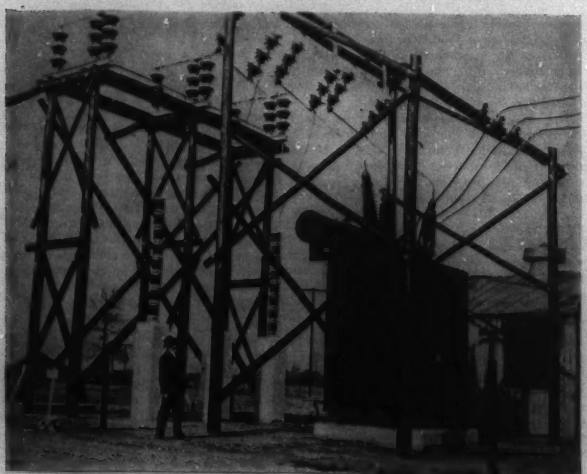
A total of 696 salesmen of steel mills, warehouses, and public utilities in the New York–Northern New Jersey region have volunteered to help the War Production Board ferret dormant scrap out of this region's industrial plants in a new intensified campaign to increase collections, according to Thomas W. Hoyt, regional salvage director. These men will discuss the scrap activities of individual plants throughout the region with presidents, plant managers, and salvage executives, reporting to the WPB on the scrap collection work in progress in each plant. When invited to do so, they will accompany salvage executives on a tour of each plant in an effort to identify additional items of dormant scrap.

Addition of more volunteers from public utilities and other industrial groups to the field corps is planned by the WPB as the program progresses, and it has been suggested that other sections of the country follow suit in a similar program.

Unused Copper Products Available for Civilian Manufacturers

Manufacturers desiring information about frozen or excess copper stocks can obtain lists of the quantities and kinds lying unused in the hands of the producers from regional offices of the War Production Board. If he has specific requirements, he should write directly to the Copper Recovery Corporation, 200 Madison Avenue, New York, N. Y. Printed forms may be obtained for submitting requests, but these are not necessary if the manufacturer will state his Controlled Materials Plan allotment number, together with the weight, description, size, and alloy of the copper products he desires. Use of material in the fabricated state would make unnecessary remelting of the stocks and would also minimize interference with the war-production schedules of mills making copper products to fill civilian needs.

Wood Substitutes for Steel on "Big Inch"



Wood substitutes for steel as superstructure for this outdoor substation at station 7 on the "Big Inch" pipeline in Arkansas. The power transformer shown is a three-phase 60-cycle 3,750-kva 110,000–2,400-volt General Electric unit

Emergency Physicists Needed

Several hundred persons from other fields who can do the work of physicists must be obtained as emergency substitutes in physical research and teaching, according to Homer L. Dodge, director of the Office of Scientific Personnel of the National Research Council.

Because of the heavy demands for research workers and teachers made upon this office in the field of physics, the supply of persons whose chief training has been in this field is exhausted. Although several hundred qualified persons are substituting already in such a capacity, reports of the National Roster of Scientific and Specialized Personnel indicate a need for several hundred more emergency physicists. All interested persons eligible to fill such positions, either in research or as teachers of beginning physics in the training programs of the armed forces, are asked to communicate immediately with Doctor Dodge, director of the Office of Scientific Personnel, National Research Council, 2121 Constitution Avenue, N. W., Washington 25, D. C.

Harbor Steam Plant Now in Service. The $9,000,000 Harbor Steam Plant of the Bureau of Power and Light of the City of Los Angeles, Calif., under construction since 1941 and recently placed in service, is an important factor in augmenting the city's power supply for war industries. The single 3,600-rpm unit now in operation is rated at 65,000 kw and weighs 466 tons; the rotating part of the equipment alone weighs 43 tons. Electricity is generated at 13,800 volts and converted to 132,000 volts in transformers located in the plant. Designed to operate either with oil or gas for fuel, the plant has an ultimate capacity of 300,000 kw. It is built to withstand an earthquake producing a horizontal force equal to ten per cent of the weight of the building plus 20 per cent of the weight of the equipment within.

New England Mica Mines Increase Production

Maine, New Hampshire, Massachusetts, and Connecticut mica mines have increased production of strategic mica according to recent reports from the mica and graphite division of the War Production Board. Although the New England mines produce only about two per cent of the United States total war consumption, the additional output does relieve somewhat the critical mica situation.

Minimum requirements of this material for immediate demands are about 20 per cent greater than the present world supply. The WPB is trying to stimulate the domestic production of mica not only to fill these requirements but also to create a more adequate stockpile. Need for mica is considered so insistent that 100 per cent increase would be desirable.

Shasta–Oroville Transmission Line Readied for 1944 Use

The Bureau of Reclamation has been ordered by Secretary of the Interior Harold L. Ickes to expedite construction of the Shasta–Oroville transmission line of the Central Valley Project in Northern California to insure an outlet for Shasta Dam power when 150,000 kw is available from the plant in March 1944.

The line, estimated at a cost of $1,900,000, will extend a distance of 98 miles from Shasta Dam down the Sacramento Valley to Oroville. The conductor will be made from 1,207,800 pounds of aluminum allotted by the War Production Board in lieu of copper. Work on the project is being accelerated at this time not only to increase power production but to aid war food output in the San Joaquin Valley through increased irrigation facilities. Hydroelectric power is needed urgently also to replace the output of oil-consuming steam-electric plants.

Radio Stations for Free French and Belgians. Two new 50,000-watt stations, supplied by the international department of the RCA Victor Division of Radio Corporation of America, are being installed on the west coast of Africa to broaden the coverage of the United Nations' radio network. The "Radiodiffusion Nationale Belge" at Leopoldville, in the heart of Belgian Congo, is already beaming daily broadcasts, primarily at Belgium, which report on the true progress of the war, and "The Voice of Free France," directed at France and all the French Colonial possessions, will soon be completed at Brazzaville in French Equatorial Africa. Both stations are equipped for RCA Radiophoto service. They are protected against tropical temperature and humidity by appropriate insulating and impregnation materials.

JOINT ACTIVITIES

Radio Technical Planning Board to Be Inaugurated September 15

Inauguration of a new Radio Technical Planning Board to plan postwar radio services and products will take place September 15 at a meeting of industry organizations concerned in New York, N. Y. Plans for the establishment of the organization have been completed by committees of the Institute of Radio Engineers and the Radio Manufacturers' Association and are being submitted to the other organizations.

The RTPB will be a technical advisory body to formulate recommendations to the Federal Communications Commission and other government and industry agencies on the technical future of radio developments. The RTPB will develop studies, investigations, recommendations, and standards as are required and submit them to the FCC and to other agencies having final authority.

The RTPB will be a representative democratic all-industry body. Initial sponsors, in addition to RMA and IRE, which will be represented at the September 15 meeting, are: AIEE, American Institute of Physics, American Radio Relay League, F. M. Broadcasters, Inc., National Association of Broadcasters, and National Independent Broadcasters. Other nonprofit radio, communications, and aeronautical groups may be included later.

Chairmen of the two committees are A. S. Wells, Chicago, Ill., for RMA and Haraden Pratt (F'37) for IRE. Other members of the committees are:

RMA: H. C. Bonfig, Camden, N. J.; W. R. G. Baker (M '41), Bridgeport, Conn.; R. C. Cosgrove, Cincinnatti, Ohio; Walter Evans, Baltimore, Md.; and Fred D. Williams, Philadelphia, Pa.

IRE: Alfred N. Goldsmith (F '20), New York, N. Y.; B. J. Thompson, Princeton, N. J.; and H. M. Turner (M '20), New Haven, Conn.

Criticism of Prime-Mover Speed Governor Specification Requested

Comments and suggestions on A Recommended Specification for Prime-Mover Speed Governing, prepared by a joint committee of AIEE and American Society of Mechanical Engineers, now available in preliminary form, are requested by the joint committee. The specification was presented at the AIEE national technical meeting, June 21–25, 1943, in Cleveland, Ohio, as a conference paper.

The present specification covers the speed governing of steam turbine generators rated at not less than 10,000 kw. The joint committee has intentionally limited the contents of the proposed recommended specification to those functional and performance characteristics that are generally believed to be the minimum requirements for satisfactory and acceptable speed governing.

The committee desires to obtain the reaction of the profession at large to this recommended specification for use as a basis for revision in advance of presentation to the AIEE board of directors and to the ASME council for approval and adoption, and as a guide for the amplification of the proposed recommended specification to include other types of prime movers. Critical examination and constructive criticism of this specification are therefore invited. An opportunity for further discussion will be afforded during the ASME annual meeting, November 29–December 3, 1943, at the panel discussion of this specification which AIEE members are invited to attend and participate in.

Copies of the proposed recommended specification are available on request from M. J. Steinberg (M '32), chairman of the joint committee on prime-mover speed governing, care of Consolidated Edison Company of New York, Inc., 4 Irving Place, New York, N. Y., and comments and suggestions about the specification should be sent to Mr. Steinberg.

Future Meetings of Other Societies

American Chemical Society. September 6–10, 1943, Minneapolis, Minn.

American Institute of Mining and Metallurgical Engineers. Electric furnace steel committee iron and steel division, October 1–2, 1943, Pittsburgh, Pa. Joint fuels conference, October 28–29, 1943, Pittsburgh, Pa. Annual meeting, February 20–24, 1944, New York, N. Y.

American Society for Metals. Annual convention, October 18–22, 1943, Chicago, Ill.

American Society of Mechanical Engineers. Annual Meeting, November 29–December 3, 1943, New York, N. Y.

American Welding Society. 24th annual meeting, week of October 18 1943, Chicago, Ill.

Association of Iron and Steel Engineers. Annual meeting, September 28–30, 1943, Pittsburgh, Pa.

National Electrical Manufacturers Association. October 25–29, 1943, New York, N Y.

National Safety Congress and Exposition, October 5–7, 1943, Chicago, Ill.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

24-Hour Time Designation

To the Editor:

In these feverish days of more and more rapid communication of all kinds, it has occurred to many that the designation of the time of day on the basis of two 12-hour cycles, with the necessity of specifying in each case a qualification that the hour is *ante* or *post* meridian, is quite obsolete.

Our European cousins for a long time have based their activities to a considerable extent on a 24-hour designation, with much resultant simplification in railroad timetables and consequent reduction of errors on the part of the public in meeting trains. The idea has not been generally accepted in this country, perhaps because of the same kind of conservatism which has inhibited adoption of the metric system

of weights and measures and the retention of feet, pounds, quarts, and degrees Fahrenheit.

Our Army and Navy have recognized the advantage of the 24-hour designation, and many thousand men and women in the Armed Forces are now familiar with the idea and base their daily routine upon it. It would seem to be an appropriate time to consider its adoption in our civilian life.

As a start, it is suggested that radio announcers who have occasion to mention the hour after noon be urged to give it on the present basis, followed by the 24-hour time. It seems to me the idea would quickly catch popular imagination, and it would be but a short step to general adoption, with its many advantages. Some individuals might desire double figures on their clocks and watches, but that would be a minor detail, and once the change is made, no further effort would be necessary.

SIDNEY WITHINGTON (F '24)

(Electrical engineer, New York, New Haven and Hartford Railroad Company, New Haven, Conn.)

Comparison of the Transform and Classical Methods

To the Editor:

In his article in the May 1943 issue of *Electrical Engineering*, Lyon presents a valuable interpretation of the problem of solving transients in electrical networks in the general case when the currents have initial values and there are initial charges on the condensers.

Of particular importance is the transformation on page 200 from the numerator of equation 6 which is a function of several of the roots to the numerator of equation 8 which is a function in the form of a polynomial of the one root p_1. If $f(p)$ is the characteristic polynomial, the denominator also may be transformed into a polynomial by means of the relationship

$$(L_1L_2-M^2)(p_1-p_2)(p_1-p_3)(p_1-p_4)=f'(p_1)$$

where $L_1L_2-M^2$ is the leading coefficient of the characteristic polynomial. If numerator and denominator of modified equation 8 at the top of page 203 are multiplied by $L_1L_2-M^2$, and double subscripts are employed, I_1 may be expressed as

$$I_{11}=\frac{\psi_1(p_1)}{p_1f'(p_1)}$$

This is identical in form with the coefficients of the partial-fraction expansion theorem. If all conditions are the same in the circuit of Figure 2 for modified equation 8 and for the operational equation for I_1 for Figure 2 on page 202, then the numerator of the operational equation for I_1 is $p_1\psi_1(p_1)$. It should be possible to prove this by algebraic manipulation. Hence, it should be possible to derive the operational solution in the partial-fraction form by the classical method. I have verified this in the case of the coupled circuit of Figure 2 for a d-c applied voltage and a stage of initial quiescence.

The coefficients in the primary and secondary currents of the coupled circuit of Figure 2 may be expressed as

$$I_{1m}=\frac{\psi_1(p_m)}{p_mf'(p_m)} \text{ and } I_{2m}=\frac{\psi_2(p_m)}{p_mf'(p_m)},$$

where $m=1, 2, 3,$ and 4

When the roots p_1, p_2, p_3, and p_4 of the characteristic equation $f(p)=0$ have been determined, the polynomials $f'(p)$, $\psi_1(p)$ and $\psi_2(p)$ may be evaluated for each root by synthetic methods such as synthetic division by a linear divisor or synthetic division by a quadratic divisor. The latter is treated on page 78 of *Advanced Practical Mathematics* by W. L. Cowley (Pitman, 1934)

Probably the most difficult part of the solution of an electrical network is the determination of the roots of the characteristic equation, particularly in the case where there are two or more pairs of complex roots. A method of locating complex roots which is as effective as any is to plot the contours $u=0$ and $v=0$ in the z plane for the purpose of determining their points of intersection. In his inaugural dissertation of 1799, Gauss made use of the asymptotic properties of these contours as the basis of his first proof of the fundamental theorem of algebra. The asymptotic properties of these contours have since received particular attention in numerous references. So far as I have been able to determine, the possibility of employing synthetic division to evaluate points on these contours has been overlooked completely. The procedure, which is easy to carry out, consists of transforming the polynomial by repeated synthetic division so as to subtract from the argument either a real numerical value or a pure imaginary numerical value. In the latter case, the synthetic division requires operations with complex numbers. This is not, however, a serious disadvantage, since the calculations can be carried out in two parts, one for the real and the other for the imaginary part. When the polynomial has been transformed either to subtract a real value or a pure imaginary value from the argument, the resulting polynomial may be separated into real and imaginary parts from which u and v may be obtained as auxiliary polynomials. The real roots of the auxiliary equation $u=0$ now determine points on the contour $u=0$ and the real roots of the auxiliary equation $v=0$ points on the contour $v=0$. When the complex roots have been located as intersection points of the contours $u=0$ and $v=0$, the calculation of more accurate values may be carried out by a method of successive approximations such as Newton's method. In connection with Newton's method, the numerical values of the polynomial and its first derivative are required for a value of the argument which approximates a complex root. The polynomial and its first derivative may be evaluated separately by available methods such as the quadratic-divisor method, or they may be evaluated by a two-stage method, for instance, the effective but slight extension of Bairstow's two-stage quadratic-divisor method given by Collatz on pages 235 and 236 of *Zeitschrift für Angewandte Mathematik und Mechanik*, volume 20, 1940.

B. K. HOVEY (M '38)

(Instructor in electrical engineering, University of Pittsburgh, Pittsburgh, Pa.)

NEW BOOKS • • •

The following new books are among those recently received from the publishers. Books designated ESL are available at the Engineering Societies Library; these and thousands of other technical books may be borrowed from the library by mail by AIEE members. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books. All inquiries relating to the purchase of any book reviewed in these columns should be addressed to the publisher of the book in question.

Air Transport Navigation. By P. H. Redpath and J. M. Coburn. Pitman Publishing Corporation, New York, N. Y., and Chicago, Ill., 1943. 612 pages, illustrations, etc., 9½ by 6 inches, cloth, $5. (ESL.)

The basic information contained in this comprehensive work is useful to the private pilot as well as to the transport pilot and navigator for whom it is intended primarily. Fundamental theories are explained, necessary instruments are described, and practical procedures for establishing and flying a course by the various methods available are discussed. The combination of dead reckoning and radio direction finding is of particular interest. Routine navigation practice, including sample log sheets, and air line flight dispatching are also covered. A wealth of ready-reference information is provided.

Electrical and Radio Dictionary. Prepared by C. H. Dunlap and E. R. Hahn. Revised edition. American Technical Society, Chicago, Ill., 1943. 110 pages, diagrams, etc., 8½ by 5½ inches, cloth, $1. (ESL.)

The main dictionary section of this book is separated into two parts, one for electrical terms and one for radio terms. In addition to these there are a brief glossary of electronic terms, a list of electrical symbols with pictorial explanations, and several pages of useful reference data.

PAMPHLETS • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Pension and Profit-Sharing Plans. Research Institute of America, 292 Madison Ave., New York, N. Y., 1943. 48 pages, $2.00.

Plan Now for Future Public Works. Construction and Civic Development Department, Chamber of Commerce of the United States, Washington, D. C., 1943. 18 pages, no charge.

TRANSACTIONS SECTION

Preprint of Corresponding Pages From the Current Annual AIEE Transactions Volume

Any discussion of these papers will appear in the December 1943 Supplement to Electrical Engineering—Transactions Section

Aircraft Contactors

F. J. RUSSELL
MEMBER AIEE

A. P. CHARBONNEAU
NONMEMBER AIEE

THE growing complexity of the electrical systems in use on modern aircraft has given rise to need for a complete line of magnetically operated switches or relays suited to conditions encountered in this type of service. Relays may be classified according to use as control relays and power relays, or in the terminology of the industrial-control engineer, relays and contactors. This paper will be confined to a discussion of power relays or contactors. Most aircraft in use at the present time have 24-volt d-c systems; consequently only low-voltage d-c contactors will be considered.

Commercial contactors of the required ratings are larger and heavier than practical for aircraft partially because

1. Conditions of use do not limit these factors so rigidly.
2. The longer life expected from them.
3. The greater insulation distances required for higher voltages.

A background of experience obtained from commercial contactors can contribute greatly to the design of aircraft switches, but numerous special conditions must also be considered. Changes in barometric pressure from 30 inches of mercury at sea level to about 5.54 inches at 40,000 feet, and temperature ranges from −50 degrees Fahrenheit to +200 degrees Fahrenheit are encountered. Vibration and shock may be met, and the switches must be designed to withstand them. Vibration tests consisting of simple harmonic motion with an amplitude of 0.03 inch (0.06 inch total displacement) and a frequency varied from 10 to 55 cycles per second have been made part of the specifications. Switches must operate in any position. Coil temperature rise must be limited to 70 degrees centigrade above a 25 degrees centigrade ambient.

Some aircraft accessories using contactors are listed in Table I. Loads are, therefore, resistance, inductance, lamps, and motors. Contactors are used on loads as low as 25 amperes and may carry 200 amperes or more. Circuit requirements may be for single-pole single-throw; single-pole double-throw; double-pole single-throw; and double-pole double-throw contactors. When used for the control of reversing motors double-throw contactors have two coils each operating a set of contacts controlling direction and mechanically interlocked to prevent simultaneous operation.

Design of a line of contactors naturally divides itself into consideration of several phases:

1. Contacts.
2. Magnet.
3. Arrangement, mounting, and special features.

These phases will be considered separately and in the order listed.

Contacts

The heart of a contactor is its contacts. The contact material must be one which does not collect a film which offers high resistance to the passage of current either when the contacts are open, while closed and heated by the current flow, or under arcing. They must therefore be made of a material which does not form nonconducting oxides and which, because of the low voltage, has a low resistance. Silver meets these requirements, but, because of transfer and welding problems, additions to the silver, as for example cadmium oxide without alloying, have been found to give superior properties. Various other additions have been proposed including cadmium sulphide, lead sulphide, tungsten, and molybdenum. The contacts must be securely fastened to the contact plates to obtain a permanent low resistance bond. Brazing is a satisfactory method. A superior product may be obtained, however, by a process in which the constituents are granulated or powdered, mixed, and molded under high pressure direct to the backing material. A grid of serrations on the backing plate interlocks with the molded material to form a secure anchor and a permanently low resistance joint. The density of the contact material may be controlled by the pressure applied in molding them. Contacts formed by this process have several important advantages.

1. A low resistance contact having the properties of silver.
2. A contact having in it other metallic materials to obtain less transfer and to reduce welding.
3. A contact with a controlled density affecting its bounce characteristics and permitting welds to be broken.
4. A contact extremely uniform and easy to manufacture.

Contacts opening and closing d-c circuits are subject to several types of failure. Transfer of material from one contact to the other in the electric arc is a well-known phenomena which has caused considerable trouble to the designers of d-c switches using contacts containing silver. Transfer occurs at any time an arc exists between the contact faces and is a function of the current in the arc. It is apparent therefore that transfer may occur during the time that the contacts are arcing when they close and also during the time the contacts are opening before the arc is extinguished. It is important that arcing time be reduced to a minimum to limit the amount of transfer. Numerous readings taken with an instrument designed for measuring arcing time[1] show that the arcing time on closure is influenced by the initial contact pressure. Figure 1*A* is a curve showing the rela-

Paper 43-131, recommended by the AIEE committee on air transportation for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21–25, 1943. Manuscript submitted April 30, 1943; made available for printing May 25, 1943.

F. J. RUSSELL and A. P. CHARBONNEAU are both with Cutler-Hammer, Incorporated, Milwaukee, Wis. Mr. Russell is supervising engineer.

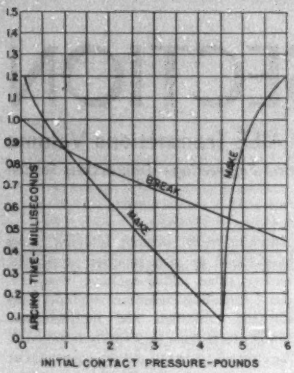


Figure 1A. Curves showing arcing time for various contact pressures

tion of arcing time to initial contact pressure for a typical contactor and shows that as the contact pressure is increased the arcing time on closure is reduced until a critical value is reached. Below this value the bounce occurs when the contact plate itself rebounds while above this value the arcing time increases because the entire moving assembly of contact and armature bounces. The weight of the moving contact plate and the armature must therefore be correlated with the initial contact pressure to obtain the most satisfactory values. Figure 1*B* shows the variation in arcing time of a contactor as the coil voltage is changed. Here again a point is reached where the entire armature and contact assembly bounces as the voltage is decreased.

The design should be such as to prevent "armature bounce" from occurring in the range of voltages over which the contactor is to operate. Reference to the curve shows that the maximum contact

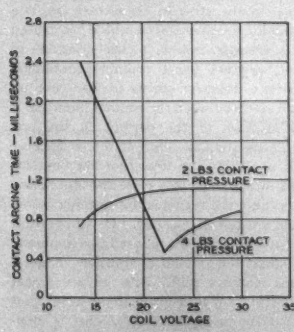


Figure 1B. Curves showing arcing time for various coil voltages

pressure is limited by satisfactory operation on low voltage (18-volts hot coil). A minimum value which will keep the arcing time on the lower part of the curve should be used to keep transfer to a minimum.

The arc formed when contacts bounce on closing may, if it is of sufficient duration or intensity, fuse the contact material and cause rapid wear. For contacts of the character stated, the molten metal is flattened and in some cases splashed when the contacts reclose. On 30 volts this begins to occur with currents of about 100 amperes. The high points are, under these conditions, leveled off so that the effects of transfer are nullified. Contacts operated above 100 amperes remain flat and have a fine granulated or mottled appearance.

Figure 3 shows typical contacts before and after being used. A typical case of transfer may be seen in Figure 3*c* while a contact which has remained level is shown in Figure 3*d*.

If the current is sufficiently high the degree of fusing may eventually cause welding. Factors which determine the current at which welding takes place include

1. The materials from which the contacts are made.
2. The thermal capacity of the contacts.
3. The degree of flattening of projections thrown up on the contact faces (controlled by the initial contact pressure).

Cadmium oxide mixed into the contacts retards the tendency toward welding and transfer and is therefore beneficial. Contacts of high thermal capacity and conductivity take the heat away from the point of arcing and reduce the amount of molten material formed. The blow which tends to flatten projections is dependent on the initial contact pressure and the velocity of closing, and it is therefore desirable to keep these values as high as possible. On opening, if the density of the contacts is low, the welds will be broken when the contacts part, particularly if a blow or shock is imparted to them. The force necessary to break the weld is determined to some degree by the materials used for the contacts and the form and size of the particles used in making them.

Contacts should have sufficient wear allowance to compensate for the wear obtained during their life and to provide for the unavoidable variations in manufacturing. The actual wear during the life required for aircraft contactors indicates that a wear allowance of 0.03 inch is sufficient to provide ample safety factor. They should have an initial contact pressure high enough to prevent welding on the highest currents which may have to be made and the pull of the magnet designed to permit this pressure to be used without obtaining armature bounce.

The arc gap required is determined by the voltage for which the contactor is to be used. A value of 0.055 inch has been selected as conservative for 24-volt service.

Magnet

There are several forms in which the operating magnet for contactors may be built. Each has characteristics which determine its suitability for a particular use. All have many common properties and a general analysis of their operation

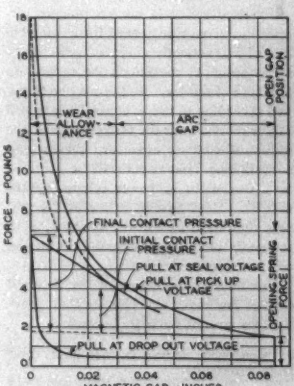


Figure 2. Contactor force analysis

may be made. Figure 2 shows a force diagram for a typical contactor. The curved voltage lines represent the pull of the magnet at various plunger positions. The forces exerted by the springs are shown by the straight lines. For convenience both the magnet-pull curves and the spring forces are plotted as if they were scalar quantities of the same direction. It should be remembered, however, that their direction of application is such as to oppose each other. At the open-gap position the plunger is kept from moving into its sealed position by the balancing or opening spring. The force required is determined by the weight of the moving parts and the acceleration forces to which the contactor may be subjected. A minimum value of $F=(A/G)\times W$ where A is the maximum acceleration to be encountered, G is the acceleration of gravity, and W is the weight of the moving parts. For balanced

structures in which accelerative forces are cancelled the force is determined by the energy required to open the contacts with sufficient velocity to insure breaking the arc quickly. As the plunger is moved toward its sealed position the opening spring is compressed so that this force increases. It is desirable that the rate of increase in this force be kept as low as possible, for an increase in its value increases the magnet pull required for a given initial contact pressure. The contacts are arranged so that they close before the sealed position of the armature is reached. The remaining portion of the stroke is wear allowance. The moving contact are fastened to the armature by means of a spring in such a manner that a force is required to separate them from it. This force is the initial contact pressure and the performance of the contacts depends considerably on its value. Reference to the force diagram shows that the upper limit of the initial contact pressure fixes the shape of the magnet-pull curve, for it is necessary if the contactor is to close smoothly that the curve passing through the initial contact pressure point be a lower voltage than the pickup voltage which is the voltage at which the magnet pull is equal to the opening spring force at the open-gap position. The shape of these curves may be altered to some extent by the shape of the pole faces. The load placed on the power system when the contacts close may be high enough to cause an appreciable drop in system voltage. For instance, the current inrush on some motors used in military aircraft has been found to be as high as 2,000 amperes. The resulting drop in voltage at the contactor coil terminals may reduce the pull to an extent that the contact will not seal completely, resulting in additional arcing of the contacts which may cause them to weld. Voltages as low as eight volts have been obtained on 24-volt systems when heavy currents were drawn. There is the further possibility, if the voltage falls low enough, that the armature may drop back even though the armature reached its sealed position. In this case the voltage drop in the arc will limit the current until the motor accelerates and the system voltage builds up enough to reclose the contactor. Operation under these conditions will burn the contacts severely and will probably result in welding. Dropout occurs when the coil voltage is decreased until the sealed pull is equal to the force from the springs tending to open the contacts. The magnet pull should decrease as the magnetic gap increases in a way so that it is less at the point where the contacts just touch than the force exerted by the opening spring to avoid hesitancy in dropping out. In other words, the curve passing through the point of zero wear allowance must be of a higher voltage than that of the drop-out curve.

The coil must have the required ampere turns to produce the necessary pull at the lowest voltage on which it is to operate. The minimum open-circuit voltage on 24-volt systems has been set at 18 volts, and therefore the pickup voltage must not exceed this value when the coil has attained its ultimate temperature. Since the temperature rise of the coil is limited to 70 degrees centigrade above a 25 degrees centigrade ambient, this final temperature is 95 degrees centigrade or the contactor must pick up on 14.2 volts when the coil is at 25 degrees centigrade if it is to operate on 18 volts with a hot coil.

The maximum voltage encountered on 24-volt systems is 28.5 volts. The coil must not exceed its allowed temperature rise when this voltage is applied. These factors fix the resistance of the coil and its radiating area.

Contractors which are not energized for sufficiently long periods to attain their ultimate temperature may have coils designed for part-time duty only. Advantage may be taken of this fact to reduce the size of coils used on intermittent-duty contactors or greater pull may be obtained from coils the same size as continuous-duty coils where special conditions must be met.

An intermittent-duty coil may be protected by the use of a resistor to make it suitable for continuous duty. The resistor is inserted in series with the coil after the main contacts have been operated. A set of auxiliary contacts are used to insert the resistor, which may be additional turns on the coil itself. The auxiliary contacts must be arranged to open after the main contacts close and the resistance value and the shape of the pole faces should be selected to keep the magnet pull greater at all points than the spring force to avoid chattering or telegraphing. See the dotted curve in Figure 3. While this type of construction permits the use of a smaller and lighter coil, the addition of the auxiliary contacts and the additional leads on the coil may completely offset the advantages of this construction. Greater difficulties in adjustment because of the accuracy required on the small switch are to be expected.

The pivoted armature type of magnet consisting of essentially a *U* having the coil mounted on one leg and using the other leg as a return magnetic path and also serving as a support for the armature pivot is a well-known and widely accepted form used a great deal in industrial contactors. The armature lever may be extended in both directions from its pivot and balanced, thereby making it more or less free from shock and the effects of vibration or acceleration. The contacts may be placed at either end of the lever, depending on whether they are to be closed or open when the magnet is energized. Coils are readily replaceable with this type of magnet. The travel of the armature lever in the closed direction is limited by the sealing of the armature face against the core face. In order to insure a reliable contact throughout the life of the contactor and to compensate

Table I. Aircraft Accessories Using Contactors

	Load
Battery disconnect	General
Engine starter	Motors
Engine synchronizer	Motors
Propeller pitch control	Motors
Wheel retraction	Motors
Flap control	Motors
Lighting	Lamps
Fuel transfer	Motors
Heating	Heaters
Gun firing	Solenoids
Bomb release	Solenoids
Turret operation	Motors

Figure 3. Contact plates

A. Backing plate showing serrations
B. Finished contact plate
C. Contact plate showing transfer
D. Contact plate after 50,000 operations at rated current

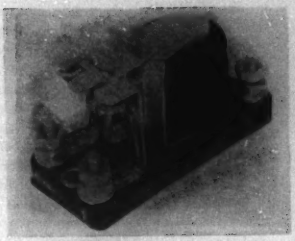


Figure 4. 25-ampere balanced-armature aircraft contactor

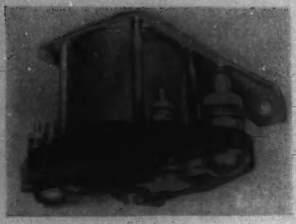


Figure 5. 200-ampere solenoid-type aircraft contactor

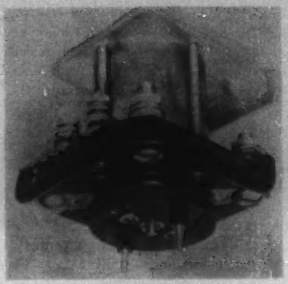


Figure 6. 100-ampere two-pole single-throw aircraft contactor

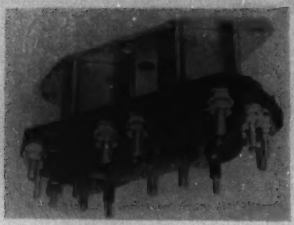


Figure 7. 50-ampere single-pole double-throw aircraft contactor

for wear of the contacts the contact faces are made to touch before the armature seals, the additional travel being taken up by providing for relative movement between the contacts and the armature lever, either using a spring for this purpose or depending on the flexing of the parts themselves. The latter method has the disadvantage, however, of requiring periodic adjustment of the contact position to compensate for contact wear, thereby causing a very rapid decrease in contact pressure unless the parts are made sufficiently flexible to give the same action as a separate spring. This is a construction frequently used in control relays where the amount of power handled and the wear is small. The pivoted-armature-lever construction can be made to cause a rolling or sliding action between the faces of the contacts which is desirable if the contact material is such as to collect a nonconductive film but which has severe disadvantages for some types of material.

Figure 4 is an illustration of a balanced-armature type of contactor rated at 25 amperes.

The ironclad solenoid type of magnet may also be used. The armature in this case is a plunger moving in the center of the coil and sealing against a stationary core member. The coil is enclosed in a shell which forms the return magnetic path and also serves as protection. The stationary contacts are mounted at one end of the coil and the moving contacts travel in a straight line to engage them. For the type of contacts being used this is an ideal arrangement because sliding or rolling on contacts of the character under discussion is not desirable. The face of the plunger in this case is conical in form to produce the desired pull curve.

A contactor of the solenoid type rated at 200 amperes is shown in Figure 5.

Arrangement Mounting and Special Features

In the design of the line of solenoid operated switches the coil is enclosed by the shell for protection and the assembly fastened together to make it a readily replaceable unit. The mounting bracket forms part of the magnetic path to conserve material and to reduce the weight. Since it is in intimate thermal contact with the coil shell and the central core, the radiation from the bracket aids in the dissipation of the heat produced in the coil. The stationary contacts are mounted on a bakelite terminal board placed on the opposite end of the coil from the mounting bracket. Iron pole pieces under the contacts serve to concentrate the magnetic field across the contact faces to obtain a blowout action. The plunger is arranged to impart a blow to the contact when the coil is de-energized by having the force from both the contact spring and the opening spring applied to the plunger in the closed position. When the coil is de-energized, the plunger moves a distance equal to the wear allowance before striking the contact plate, thereby tending to break any weld that should be found.

Double-pole single-throw contactors are similar to the single-pole contactors, except that a second set of contacts is provided. Figure 6 shows the 100-ampere two-pole contactor.

The reversing contactor shown in Figure 7 consists of two single-pole or double-pole contactors mounted on a common bracket and having a common terminal board. An interlocking bar to prevent simultaneous operation permits either contactor to be operated independently.

Conclusion

Contactors designed particularly for use on aircraft may be smaller and lighter than those having comparable current ratings used commercially. In order to obtain the most satisfactory design careful consideration must be given to the basic requirements and to the conditions of operation. Analysis of the functions of the component parts makes it possible to design them to obtain contactors having maximum flexibility in application, minimum maintenance for long and dependable operation, and smallest size.

Reference

1. An Instrument for the Determination of Contact Making and Breaking Time, Walther Richter, William H. Elliot. AIEE Transactions, volume 62. 1943. January section, pages 14–16.

Interim Report on Application and Operation of Out-of-Step Protection

AIEE RELAY SUBCOMMITTEE

Preface: The present war emergency requires that the maximum use be made of existing equipment and systems and that a minimum of critical material be used for new equipment.

This publication and other guides and reports in this series have been prepared for the information of users during the war emergency. Upon termination of the war emergency they will be reconsidered by the Standards committee and the committees which prepared them, and will be approved, revised for normal use, or rescinded.

This procedure is being followed in preference to the preparation of special emergency standards which might involve redesigning and drastic changes in manufacturing practices. These guides will accomplish the maximum conservation of critical materials, since they provide for the maximum use of existing equipment and systems, as well as new equipment without changing the fundamental basis on which the present standards have been prepared.

Synopsis: Out-of-step protection of synchronous machines and system interconnections is now demanding serious consideration, first because the heavy loading of machines and transmission lines has introduced many stability problems and secondly, because outages resulting from out-of-step conditions may interfere seriously with the war effort. The relay subcommittee has, therefore, considered it timely to prepare a report on the subject and has appointed a working group for that purpose.

The report describes briefly out-of-step phenomena, the methods of protection that are available, and a cross section of the practices and requirements of representative utility systems.

Out-of-Step Phenomena

IT is well recognized that when a synchronous machine pulls out-of-step with another synchronous machine or group of machines, a violent disturbance is set up which may damage the machines and cause undesirable operation of relays used to protect against overload or short circuit. Detailed explanations of the actual phenomena have been published.[1-9] It is believed, however, that a brief review of the behavior of the current and voltage during an out-of-step condition may enlighten the discussion on the application of devices and methods for protecting machines, for blocking undesirable tripping of fault protective relays, and for opening interconnections at selected points during out-of-step conditions.

A synchronous machine can be represented by an equivalent reactance and an internal voltage. For steady-state conditions, this equivalent reactance is equal to the synchronous reactance modified in accordance with the machine excitation. For sudden changes in armature current, such as those that occur during an out-of-step condition, the equivalent reactance is generally more nearly represented by the transient reactance of the machine.

When two synchronous machines are paralleled, the current interchange between them is determined by the vector difference of their internal voltages applied to the interconnecting impedance, which includes the reactance of the machines as well as any impedance between machines. Neglecting charging current and any tapped-off load current, the current is the same at all points in the interconnection and lags the difference voltage by the impedance angle of the interconnection. The voltage at any point is equal to the internal voltage of the leading machine minus the impedance drop to the point. See Figure 1. With this basic understanding it is possible to determine either analytically or graphically the magnitudes and relative phase angles of the current and voltage at any point in an interconnection for any magnitude and angular separation of internal voltages.

When the machines pull out of step, the internal voltages swing apart through an angle of 360 electrical degrees for each complete slip cycle. As this angle of separation progresses, it causes a difference voltage which starts at a minimum for the inphase position, builds up to a maximum at 180 degrees out-of-phase, and decreases again to a minimum at 360 degrees. Therefore, there will be pulsations in current and voltage at every point in the interconnection. The current will pulsate in magnitude similarly to the difference voltage; that is, it will be a minimum for the inphase position and a maximum at 180 degrees out-of-phase. The voltage at any point will also pulsate in magnitude, but it will be a maximum for the inphase position and a minimum at or near 180 degrees out-of-phase. The minimum value will vary throughout the interconnection, reaching zero at one point which, for equal internal voltages, would be the electrical center of the interconnection. If the internal voltages are unequal, the point of zero minimum voltage will be proportionally nearer the end of lowest internal voltage.

The curves of Figure 1 show how the interchange current, the voltage, and the angle between the two vary during a complete slip cycle at two points in a typical interconnection. Equal internal voltages and no intermediate load are assumed. The points shown are the high-voltage busses at each end of an interconnection consisting of a synchronous machine and transformer at each end with a 60-degree impedance line between. From these curves, it is possible to predict the performance of voltage-, current-, watt-, or distance-type relay elements located at each end of the line, taking into account the relay connections and the period of a slip cycle.

Protection of Individual Synchronous Machines

Individual synchronous machines can be protected against out-of-step operation by devices that recognize a condition which may cause pull-out unless corrected or by devices that detect an actual out-of-step condition. The more complete protection would include devices of both types. In general, the degree of protection warranted depends on whether the station is automatic or attended, whether the machines are generators or motors, and upon the importance of the machine.

Before Loss of Synchronism

A synchronous machine may pull out of step because of any one or a combination of the following conditions:

1. Load in excess of pull-out with normal excitation.

Paper 43-119, recommended by the AIEE committee on protective devices for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21-25, 1943. Manuscript submitted April 22, 1943; made available for printing May 19, 1943.

Personnel of the working group on out-of-step protection of the relay subcommittee: H. R. Vaughan, *sponsor*; C. R. Mason, G. Steeb, J. H. Vivian, E. E. George, R. W. Knapp, J. T. Logan, J. J. Samson, R. C. Sawyer.

This interim report was prepared by the working group on out-of-step protection of the relay subcommittee of the AIEE committee on protective devices for the purpose of making essential information immediately available to war industries, thus furthering the conservation of valuable material for the war emergency. It is educational and in no way mandatory. It is not intended as a "Standard," and has not been approved formally by the Standards committee nor the board of directors.

Acknowledgment is given to L. N. Crichton (deceased) and to C. R. Mason for the preliminary report that each prepared while he was serving as sponsor of the group.

Table I. Summary of Replies to Questionnaire

Operating Company	Question Number from Questionnaire 1	2	3	4	5	6	7	8	9	10	Comments
A	Yes	Field failure and reverse current relays on field feeders—record good	Trip	None. Operators instructed to trip if out-of-step exists for extended time	Alarm	Yes	Yes	Time delay on carrier tripping	c	Incorporated as part of relay scheme	Stability problem has been reduced by carrier relaying, set to give about 15 cycles clearing time. Carrier relaying has adjustable time delay to allow electrical center of out-of-step condition to shift through line section. Some difficulty in trying to set for selective tripping
B	Yes (Frequency changers)	Overload relays used to disconnect frequency changers in case of pull-out	Trip	None	Trip	No	No	None	a	Keep relaying schemes separate	Steam stations rigidly interconnected
C	Yes	Detection of condition left to operator	Trip	Operator must identify condition	Trip	No	Yes (on swing)	None	a	———	Closely coupled system. No cases of actual instability in 15 years. Severe load swings with interconnected system have caused line relays to trip
D	Yes	None	Alarm	None	Alarm	Yes	Yes	Carrier relaying with out-of-step blocking	c	Separate	Blocking relays available with carrier relays but not necessary where located at present time
E	Yes	Some generators equipped with overload relays with long time setting	Alarm	Same as (2)	Alarm	Yes	Yes	Carrier relaying with blocking	b	———	In one case of loss-of-field, overload relays tripped generator. In another case, generator slipped poles for a minute or two without relays tripping and pulled back in step when excitation was gradually restored
F	Yes	None	Trip	None	Trip	Yes	Yes	None now. Carrier relays with blocking being installed	c	No experience	Hope to arrange out-of-step blocking so that system will separate at point where it can be conveniently resynchronized
G	Yes	None at present	Alarm	None at present	Trip	Yes	No	None	c	Separate	Loss of or underexcitation considered serious subject. Different machines behave differently. Protection should probably be made to fit characteristics of machine
H	Yes	Generators none. Synchronous condensers have overload protection	Trip	None	Trip	Yes	Yes	None	c	Incorporate in line relays if possible	In some instances might be desirable to block tripping for one or more slip cycles and then permit tripping if synchronism is not regained. Number of slip cycles of blocking should be adjustable. Relays should be blocked from tripping caused by power swings on electrically long lines
I	Yes	None	Trip	None	Trip	Yes	Yes	None at present		Separate	Numerous cases of pull-out between steam plant and small hydroelectric plant and with neighboring system interconnected through long tie. Relays that normally operate during out-of-step split system at neutral load point without serious inconvenience
J	Yes	None on generators. Overcurrent protection on large synchronous motors	Alarm	None except overcurrent relays on large sychronous motors	Alarm	Yes	Yes	At tie points between load areas, line relays are induction type with long time reset to act as notching relays during out-of-step	c	Separate if possible and practicable	Line relays not blocked during out-of-step, but settings are graded to favor tripping at preselected points. System being essentially metropolitan with high load densities is relatively stable
K	Yes	None. Operators instructed to recognize condition	Trip	None	Trip	Yes	Yes	None	c	Incorporate in line relays where possible	Most cases of machine pull-out caused by underexcitation. Line relays always operate at one or more locations in case of system instability. Neglecting economics of installation, would prefer to block all line relays subject to out-of-step tripping except at selected locations where tripping causes the least loss of load and permits quickest restoration of ties
L	Yes	One machine has instantaneous overcurrent relay set above load current to cut out portion of field resistance	Alarm	None	Trip	Yes	Yes	None	c	No opinion	Recent extended interconnections expected to add to out-of-step problems
M	No (Large generators)	None except to trip large generators off line in case of loss of excitation	Trip	None	Trip	Yes	Yes	Blocking and selective tripping scheme which operates with line impedance relays without carrier current satisfactory	c	In some cases desirable to have blocking devices separate. Most desirable line-relay settings may not be best for blocking devices	Operating record for out-of-step blocking scheme for three years. 13 correct desirable, 6 undesirable but correct for the conditions existing, 3 incorrect

N	Yes	None. Unusual operation of voltage regulator gives audible signal that trouble exists	Trip	None except voltage regulator as in (2)	Trip	One case	Yes	None				
O	Yes	On small semiautomatic station use control relay to trip field of alternator to shut down machine after time delay in case field current drops to zero. Not used on major generators	Alarm	None	Trip	Yes	Yes	None		[b] Incorporate in line relays		Operators are educated by discussions, illustrated by moving pictures of meter action during actual out-of-step, to recognize machine causing trouble. This system is relatively compact so that instability is not probable if faults are cleared reasonably fast. A reliable scheme of positive detection that a particular machine is out-of-step would be desirable
P	None lately	Transient load anticipator on one machine only	Alarm	None	Alarm	Yes	No	Blocking in conjunction with carrier where carrier relaying is used. Record is good	[c] No experience except in conjunction with carrier	Incorporate in line relays if it does not unduly complicate the protective relays	System is operating near stability limit because of heavily loaded generators at high power factor and highly fluctuating load	

2. A sudden change of large magnitude in load.

3. Drop in applied voltage (motor).

4. Abnormally low or complete loss of excitation.

Complete protection against probable loss of synchronism involves devices that will detect any one of the aforementioned conditions.

Load in Excess of Pull-Out With Normal Excitation

In general, the steady-state pull-out torque of a synchronous machine with normal excitation involves currents in excess of the thermal capacity of the machine; so devices provided for overload protection will also protect against steady-state pull-out caused by overload. Such devices are usually thermal- or overcurrent-type relays set either to shut the machine down or to sound an alarm. Where the overload device does not provide protection against steady-state pull-out with minimum operating excitation, such protection may be provided by a kilowatt relay set below the minimum pull-out load or by a load limiting device on the prime mover.

Sudden Change in Load

Sudden load changes on generators are usually caused by system faults, loss of large blocks of power, or by tripping off of other generating equipment. When the load change exceeds the transient stability of the machine, the machine will usually pull out of step so quickly that an overload device for detecting probable loss of synchronism is of little value. Automatic voltage regulators and exciters with high speed of response are used as corrective devices. Also in operation are load anticipators for steam turbine generators, which respond to sudden changes in load but which are not affected by gradual changes. The normal function of this device is to initiate a change in steam flow to the prime mover corresponding to a sudden change in load without interfering with the normal functioning of the governor for gradual changes in load.

An inertia relay[1] which responds to rate of frequency change has been developed primarily to expedite immediate circuit reclosure. Two out-of-step protective schemes are being installed which make use of this relay to detect approaching instability through the rate in frequency change as reflected in voltage phase shift. A watt relay is employed to block the inertia relay for system swings resulting from high-speed clearing of faults which do not cause loss of synchronism.

Drop in Applied Voltage

The pull-out torque of a synchronous motor varies almost directly as the applied voltage. A substantial drop in voltage of more than a few cycles duration is therefore quite likely to cause loss in synchronism. Synchronous motors are usually provided with undervoltage protection to prevent continued operation at reduced voltage or reapplication of improper voltage after shutdown. However, this undervoltage protection should have time delay to prevent unnecessary trip-outs on momentary voltage dips and therefore should not be depended on to anticipate an out-of-step condition.

Loss of Excitation

The field excitation of a synchronous machine has an important bearing on its pull-out torque. Figure 2 shows how the steady-state pull-out between a typical turbine generator and power system varies with excitation. Protection against field failure, or inadequate excitation for a given generator output, is desirable from the standpoint of pull-out if it does not otherwise detract from operating reliability.

The American Standards Association Standards for Automatic Stations recommends loss-of-field protection for all types of machines having fields. This is usually provided by an undercurrent relay in the field circuit to trip and lock out a machine that has lost its excitation. If the station is attended, an alarm may be sounded instead. The undercurrent relay should have sufficient time delay to ride through transient conditions of low field current immediately following external short circuits. Either the drop-out current of the relay must be low enough to allow generation at minimum excitation requirements, or its contact circuit must be disconnected during this operating condition. The relay may also be interlocked with the generator or line breaker so that it is operative only when the machine is on the line.

The main function of an undercurrent relay in the field circuit is to detect loss of field because of open circuits in the field or a failure in some part of the excitation system. It does not provide positive protection against inadequate excitation for a given generator output. Furthermore, it would not always be fast enough, if time delay is intentionally provided, to disconnect a machine with inadequate excitation before synchronism is lost.

[1] Some companies have rigid operating instructions regarding the minimum excitation current permitted for a given

generator output. This quantity has generally been under the manual supervision of an operator, but it could be supervised automatically by balancing the kilowatt load against the d-c field strength. Automatic voltage regulators can be compensated to assure adequate excitation, or for generators they could be interlocked with the prime mover throttle so that the generator could not operate with a low field at full throttle. They could also be provided with a device to limit regulator action to a predetermined minimum field current and to indicate when this excitation existed.

When a generator loses field, it draws excitation from the system. Reactive kilovolt-ampere flow into the generator can therefore be used as an indication of inadequate excitation. A more positive scheme is to use reactive current, since the reactive kilovolt-amperes may be held down because of a severe drop in voltage. There are several installations[3] of this type. Reactive current is measured by means of a polyphase reactive kilovolt-ampere relay, with a voltage regulator to maintain a constant voltage on the relay. The reactive-current relay is interlocked with an undervoltage relay in the bus to prevent tripping unless the bus voltage is low enough to make operation of the generator unsafe. The combination is sensitive to the effect of a serious reduction in excitation, regardless of how it is caused, and removes a machine from service quickly enough to minimize the effects of field failure on the rest of the system.

After Loss of Synchronism

A relay operating on current alone, voltage alone, or directional current alone cannot be depended upon to discriminate between an out-of-step condition and a system disturbance. An overcurrent relay with pick-up above maximum load current and time delay greater than maximum fault clearing time may not close its contacts during an out-of-step condition, particularly if the excitation of the machine is low. If the relay pick-up and time delay are set low enough to operate for an out-of-step condition, the relay is quite likely to operate during the period of hunting following a system disturbance. A directional overcurrent relay would have the same weakness. Likewise, a voltage relay with its drop-out set low enough to ride through a fault condition might not operate during out-of-step unless the machine impedance were high so that the terminal voltage would dip to a low value.

A more reliable scheme of protection makes use of a notching element actuated by out-of-step impulses. The notching relay trips the machine or sounds an alarm after a given number of pole slippages, usually three to five pairs. The notching element may be either a mechanical device or a counting chain of auxiliary relays arranged so that each link will notch up in succession as successive out-of-step impulses are given to it.

The notching prerequisite makes it possible to use more sensitive impulse-detecting relays without the possibility of tripping at the time of a line fault. A single impulse will be given to the notching element at the time of a fault. It is therefore necessary to reset the device after each system short circuit. Otherwise, repeated short circuits would eventually cause tripping. This resetting operation can best be performed automatically by means of a timing relay which is set in motion by the first notch and arranged to reset the notching element if the notching sequence is not completed within a specified time.

The total number of notches in the sequence should be as small as possible to minimize stress on the machine and disturbance to the system. However, it must be large enough to insure against operation from other system disturbances, as for example the impulses caused by the successive reclosing of a line breaker. A notching sequence constituting a pole slippage of three to five pairs of poles will usually provide sufficient margin.

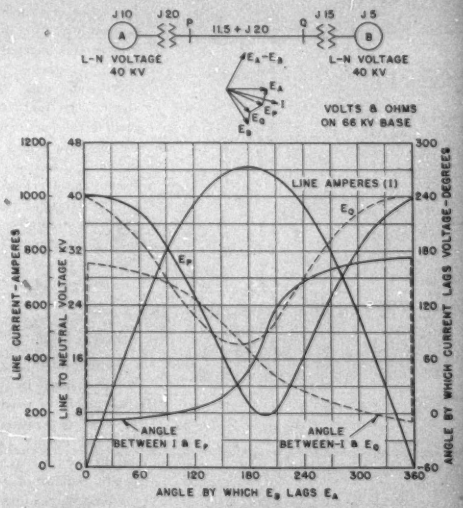


Figure 1. Behavior of the current and voltage at each end of a typical interconnection during a slip cycle

An overcurrent or an undervoltage relay may be used to actuate the notching element. However, it may be difficult to set an overcurrent relay to discriminate between a hunting condition and an out-of-step condition. Also, the voltage dip at the machine terminals may not be enough to drop out a voltage relay positively. A more reliable scheme makes use of a duodirectional watt relay and an overcurrent relay, with their contacts connected in series as shown schematically in Figure 3. The alternate closing of the forward and reverse contacts of the watt relay with the overcurrent relay contacts closed will notch up the notching element.

The watt relay prevents the overcurrent relay, which may be set to less than full-load current, from notching up because of changes in load current. The object of the overcurrent relay is to prevent the watt relay from notching up during hunting. If the machine hunts during light load, the watt relay will follow the oscillations, but the current will normally not be high enough to operate the overcurrent relay. If the machine is carrying a heavy load the current element might pick up, but the power surges during hunting will normally not reverse in direction, and the watt relay would not close its reverse contacts. The combination thus provides reliable out-of-step protection except when the machine pulls out because of complete loss of field. A cylindrical-rotor machine without field excitation may operate as an induction

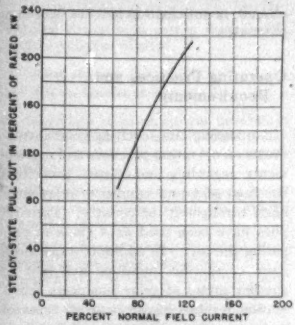


Figure 2. Effect of field excitation on steady-state pull-out of typical generator and system

generator at one or two per cent slip without reversal of power. The best protection against out-of-step operation from this cause is a field-failure relay.

Where there are several generators bussed together in a station, the out-of-step relays may have to be supplemented by a discriminating relay to indicate which machine is actually out of step. This might be a directional impedance relay used to indicate the direction of the electrical center, which would normally fall within any one machine that pulled out of step with others in a station. The difference in reactive current flow in the various machines might also be used as a discriminating factor. It is not known whether there are any such applications.

It is common practice to provide relays that will remove the field excitation from synchronous motors of moderate size when they pull out of step and reapply excitation at the proper time for resynchronizing. The power factor of the current flow into the motor has been used as an indication of loss of synchronism. In addition to power-factor relays, there are several relays designed especially to remove the field excitation on pull-out and reapply excitation for resynchronizing. One of these is the "slip-cycle impedance" relay which operates on the variations in impedance of the armature winding of the motor that occur during each slip cycle of out-of-synchronism operation. Another type of relay used for this purpose is the "field-frequency" relay which responds to magnitude and frequency of voltage generated in the field circuit. Also available is a "synchromatic" relay which responds to speed as a function of armature current and to time. There are many of these types of relays in successful operation.

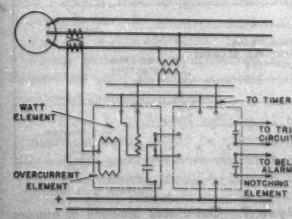


Figure 3. Out-of-step notching relay for protection of synchronous machines

Protection of Transmission Lines

Before Loss of Synchronism

Loss of synchronism between generating stations or between power systems is generally caused by some transient disturbance, such as a transmission line fault or a sudden load change. The ability of the interconnection to maintain synchronism during such a disturbance depends mainly on the speed of fault clearing and the angle between stations previous to the fault. The speed of fault clearing is fixed by the fault protective devices. However, the angular shift through the interconnection depends upon the load being interchanged and the impedance of the interconnection, both of which may vary. Either one or both of these quantities could serve therefore as a warning against possible loss of synchronism in case of a disturbance.

A watt relay can be used to sound an alarm or make a load correction when the load interchange reaches the allowable limit for a given impedance. However, load magnitude is not a reliable indication where the impedance is liable to change.

There is in service one group of relay installations intended to measure the angle between systems. The interconnections consist of both high- and low-voltage ties between systems. Stability cannot be maintained through the low-voltage tie in the event the high-voltage tie opens. A voltage relay is energized from a differential circuit supplied with voltage from each system. When the systems are over 60 degrees out-of-phase the relay operates to warn that something must be done immediately to relieve the condition.

Remote control by carrier-current telemetering offers possibilities of automatically giving an alarm or adjusting load interchange to conform to system conditions. There is one installation[3] where the receiver system phase angle is compared with the sending system phase angle by means of carrier current over a distance of 460 miles. The interchange is automatically controlled by this comparison of phase angle.

After Loss of Synchronism

When interconnected generating stations or power systems pull out of step, it is generally desirable to open the interconnection at such a point that system operation is least disturbed. However, all the fault protective relays in the interconnections are subjected to out-of-step current and voltage pulsations, and this may cause circuit breakers to be tripped at one or more undesirable locations. The usual function of out-of-step relays as applied to transmission lines is therefore to block undesirable tripping. They may also be used as out-of-step tripping relays to open rapidly the tie breakers at preselected locations during out-of-step conditions.

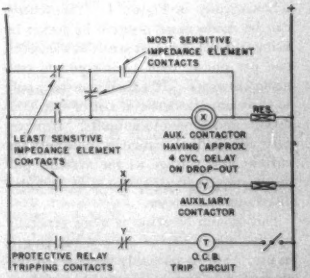


Figure 4. Out-of-step relay for blocking the trip circuits of fault-protection relays during out-of-step conditions

Relays operating on residual current or voltage for ground-fault protection are not affected during out-of-step, since the pulsations are balanced between phases. Also, parallel-line balanced-current relays and current differential relays, such as those used in a-c pilot-wire relaying, are not affected. However, overcurrent relays, undervoltage relays, distance-type relays, and directional coruparison relays, such as those usually employed with carrier-current relaying, are susceptible to operation during out-of-step conditions. Distance relays can be provided with phase-angle characteristics to be less sensitive to system oscillations than to faults.

Most out-of-step relays for transmission-line protection make use of the gradual change in current or voltage or both in discriminating between a fault and out-of-step condition. Two elements differing in sensitivity enough to give a few cycles of time delay between pick-up as the two systems pull apart are used. Overcurrent elements can be used

if the interconnected generating capacity is essentially constant, so that the out-of-step current can be safely predicted. Impedance elements are better suited, however, because the ratio of voltage to current during out-of-step conditions varies over a greater range and is more nearly independent of generating capacity. The impedance elements may be the same as those used for fault protection, or they may be separate from the fault-protective relays. If a fault occurs within the protected zone, both elements operate substantially together and the out-of-step feature is made inoperative. However, if there is a relatively slow decrease in the measured impedance, such as that characterized by a system oscillation alone, one element operates before the other, and an auxiliary relay is operated either to trip or to block tripping as desired.

A typical out-of-step relay is shown schematically in Figure 4. The scheme can be made more positive in action by using three of the most sensitive elements, one per phase, with their contacts connected in series. It is then necessary only to discriminate between out-of-step conditions and three-phase faults. If necessary, the gradual change in angle between current and voltage as the systems pull out of step could also be used as an added discriminating factor.

Out-of-step blocking is more generally applied where carrier-current relaying is in use. This is probably because carrier-current relaying is commonly used on systems subject to instability and because out-of-step blocking can be readily adapted to carrier relaying. The blocking may be accomplished either by opening the trip circuit at each relay location during the out-of-step tripping impulse, or by transmitting a carrier signal through the slip cycle when an out-of-step condition is indicated.

A typical scheme of blocking the trip circuit is shown in Figure 5. The same distance-type elements are used for carrier control, for backup protection with the carrier out of service, and for indicating an out-of-step condition. Auxiliary contactors are used to block the tripping circuit during the period of a slip cycle if a three-phase-fault indication in the backup zone persists for approximately four cycles before the local carrier receiver relay closes its contacts indicating an internal fault. As indicated in Figure 1, impedance-type fault-detector elements would operate before the slip cycle advanced far enough to indicate an internal fault. This scheme can be made operative with the carrier out of service and the relays operating as distance type.

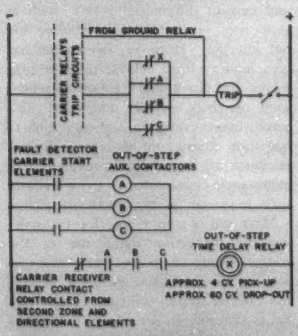

FROM GROUND RELAY
CARRIER RELAYS TRIP CIRCUITS
TRIP
FAULT DETECTOR CARRIER START ELEMENTS
OUT-OF-STEP AUX. CONTACTORS
OUT-OF-STEP TIME DELAY RELAY
CARRIER RECEIVER RELAY CONTACT CONTROLLED FROM SECOND ZONE AND DIRECTIONAL ELEMENTS
APPROX. 4 CY. PICK-UP
APPROX. 60 CY. DROP-OUT

Figure 5. Out-of-step blocking combined with carrier-current relaying. Trip circuit is blocked during out-of-step period

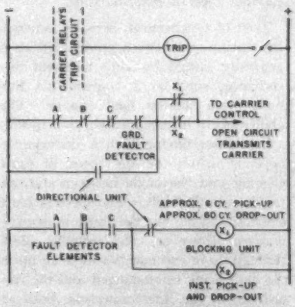


Figure 6. Another method of combining out-of-step blocking with carrier-current relaying. Carrier signal is transmitted to block tripping during out-of-step period

A typical scheme of blocking by transmission of carrier signal is shown in Figure 6. An auxiliary blocking unit causes a carrier signal to be transmitted during the out-of-step period when a three-phase fault indication in the nontripping direction persists for some six cycles at either terminal.

There are some installations where the elements of distance relays used for fault protection without carrier are also used for out-of-step blocking or tripping. This is usually done as shown in Figure 6. By means of a control switch the out-of-step relay can be set to either block tripping or to trip on the first out-of-step swing.

In some carrier-current installations high-speed tripping is sacrificed in an attempt to prevent tripping during out-of-step conditions. Other schemes in use transmit blocking carrier for a short time after an external fault has been cleared, in anticipation of a heavy system oscillation.

Operating Practices and Requirements

A questionnaire soliciting general comments on operating practices and requirements regarding out-of-step protection has been sent to a number of relay engineers throughout the country. Their replies have been used as a guide in preparing the text. In addition, a questionnaire of specific questions was sent to another group of relay engineers representing utilities having various types of interconnections. It is believed that their replies give a fair cross section of actual practices and requirements. The questionnaire read as follows:

1. Have any cases of synchronous-machine pull-out occurred on the system you represent?

2. What precautions, if any, are employed to recognize a condition such as sudden overload or loss of excitation that might cause a synchronous machine to pull out of step? Please explain the principle of the scheme of protection used and its operating record.

3. Which of the following do you consider the most desirable in case of the loss of excitation on a major generator:

(*a*). Sound an alarm.

(*b*). Trip the machine off the line.

(*c*). Automatically transfer to an emergency source of excitation.

4. What scheme of protection, if any, is used to detect that a machine has pulled out of step? What is its operating record?

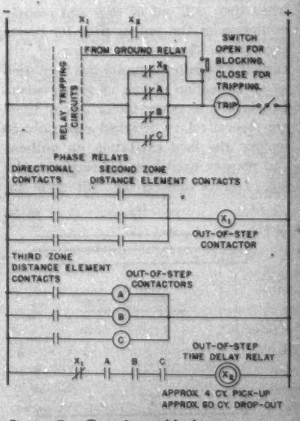


Figure 7. Out-of-step blocking or tripping combined with fault-protection relays without carrier current

5. Which of the following do you consider the most desirable in case a synchronous machine pulls out of step?

(a). Sound an alarm.

(b). Trip the machine off the line.

6. Have any cases of system instability, that is, instability between systems or between generating stations, been experienced?

7. Have there been any cases where out-of-step or severe system swings have caused line relays to operate?

8. What scheme, if any, is used to block tripping of line relays during out-of-step or to separate the system at a selected point? Is the scheme used with or without carrier current? What is its operating record?

9. Which of the following schemes of operation do you consider most desirable?

(a). Provide no out-of-step blocking and let the line relays trip where they may.

(b). Provide blocking of all relays that are liable to trip during out-of-step with the thought that stability will be regained.

(c). Provide blocking of all relays that are liable to trip during out-of-step except those at one selected location where out-of-step tripping is least objectionable.

10. Do you consider it desirable to keep the out-of-step blocking devices entirely separate from the line relays or to incorporate them in the line-relaying scheme if possible?

11. Miscellaneous comments.

A summary of the replies to the questionnaire is given in Table I.

General Conclusions

1. Practically all operating companies have had synchronous machines pull out of step because of loss of excitation or some other disturbance.

2. It is not general practice to provide generators with means of detecting disturbances that might cause the machine to pull out of step. Some have reverse-current or undercurrent relays in the field circuit, and at least one company protects against inadequate excitation by measuring the reactive current taken by the generators. Quite a few provide partial protection by means of overcurrent relays, although it is recognized that this does not provide positive protection against out-of-step operation. Large synchronous motors and synchronous condensers are quite generally supplied with protection against loss of field.

3. There is a divided opinion as to whether an alarm should be sounded in case a major generator loses excitation or whether the machine should be tripped off the line. Most operators seem to prefer tripping.

4. It is not general practice to provide special devices for detecting when generators pull out of step. Large synchronous motors and synchronous condensers are often provided with some degree of protection by overload relays. Some are provided with out-of-step relays.

5. There is a divided opinion as to whether an alarm should be sounded when a synchronous machine pulls out of step or whether it should be tripped off the line. The majority seem to favor tripping. There is a feeling that if a generator pulls out of step because of loss of excitation it will not regain synchronism without excessive disturbance if excitation is restored. It is generally felt that a machine will be seriously damaged if it is not tripped immediately. However, there have been cases where turbine generators have pulled out of step because of loss or reduction of excitation, have run for a minute or two as induction generators, and then pulled back into step when excitation was restored. Inspection showed no apparent damage.

6. Practically all utilities, except those consisting of steam stations connected rigidly together electrically, have experienced system instability.

7. Most utilities have experienced undesirable operation of fault-protective relays as a result of system instability.

8. Quite a number of utilities attempt either to block line relays from tripping because of out-of-step conditions or to set the relays so that tripping will occur at a preselected point. Out-of-step blocking in conjunction with carrier relaying is the method most commonly used.

9. Most utilities would prefer to provide blocking of all relays that are liable to trip during out-of-step except those at one selected location where out-of-step tripping is least objectionable. Some use out-of-step relays for tripping where fault-protection relays cannot be depended on to trip during out-of-step operation.

10. There is a divided opinion as to whether out-of-step devices should be kept entirely separate from the line relays or whether they should be incorporated in the line-relaying scheme if possible. There may be applications where the settings of the elements for out-of-step protection should be different from those for fault protection. In some cases there is an advantage in having the out-of-step devices separate from the line relays.

11. Most operators agree that, where possible, consideration should be given to strengthening interconnecting ties between systems and to decreasing fault clearing time in an effort to prevent instability. However, this cannot always be economically justified. Also, the war has made it necessary to explore every possibility to attain maximum utilization of existing equipment. Out-of-step blocking and selective tripping provide one effective way of doing this.

12. There are out-of-step devices and methods available that will meet most requirements if applied properly. However, operating experience with some of them is limited. There is an apparent need for further investigation of the action of out-of-step relays during certain conditions. Among these are:

(a). A prolonged fault during out-of-step.

(b). The closing of a circuit breaker on a system out of step.

(c). Out-of-step operation through a long high-voltage line where charging current is to be reckoned with.

References

1. Inertia Relay Anticipates to Facilitate Reclosure, J. T. Logan, H. Miles. *Electrical World*, volume 113, 1940, pages 1061–4.

2. Loss-of-Field Protection for Generators, G. C. Crossman, H. P. Lindemuth, R. L. Webb. AIEE Transactions, volume 61, 1942, May section, pages 261–5.

3. Phase-Angle Control of System Interconnections, R. E. Pierce, R. W. Hamilton. AIEE Transactions, volume 58, 1939, March section, pages 83–92.

4. Time Sequence Relay for System Separation, Charles L. Betts. *Electrical World*, December 26, 1942, page 42.

5. Out-of-Step Blocking and Selective Tripping With Impedance Relays, H. R. Vaughan, E. C. Sawyer. AIEE Transactions, volume 58, 1939, December section, pages 637–46.

6. Relay Operation During System Oscillations, C. R. Mason. AIEE Transactions, volume 56, 1937, July section, pages 823–32.

7. Distance Relay Action During Oscillations, E. H. Bancker, E. M. Hunter. AIEE Transactions, volume 53, 1934, pages 1073–80.

8. Fault and Out-of-Step Protection of Lines, H. D. Braley, J. L. Harvey. AIEE Transactions, volume 54, 1935, February section, pages 189–200.

9. A System Out of Step and the Relay Requirements, Leslie N. Crichton. AIEE Transactions, volume 56, 1937, October section, pages 1261–7.

10. Experiences With a Modern Relay System, G. W. Gerell. AIEE Transactions, volume 55, 1936, October section, pages 1130–6.

11. First Report of Power System Stability, AIEE subcommittee on interconnection and stability factors. AIEE Transactions, volume 56, 1937, January section, pages 261–82.

12. Protecting Frequency Changers From Out-of-Step Condition, L. N. Crichton. *Electric Journal*, February 1937, pages 71–6.

13. Grounding Against Loss of Field, E. H. Bancker. *Electrical World*, January 1933, page 983.

14. Synchronous Motor Excitation Controlled by New Relays, N. L. Hadley. *Electrical World*, April 1933, pages 550–1.

15. Performance Requirements for Relays on Unusually Long Transmission Lines, F. C. Poage, C. A. Streifus, D. M. MacGregor, E. E. George. AIEE Transactions, volume 62, 1943, June section, pages 276–83.

Distance Relay Protection for Subtransmission Lines Made Economical

L. J. AUDLIN
MEMBER AIEE

A. R. van C. WARRINGTON
ASSOCIATE AIEE

Synopsis: Less important transmission lines are usually protected with directional overcurrent relays. Much better protection and consequently improved service would be provided by modern high-speed distance relays but at several times the cost. What is required is a distance relay arrangement considerably less expensive than the relays now used on high-voltage transmission lines but with as nearly as possible the same characteristics. Such an arrangement is now available. The paper describes successful tests in the laboratory and on an actual system in this country with both natural and staged faults.

The equipment consists of a single high-speed reactance relay which is enabled to protect all three phases by being automatically switched to the correct potential and current by a phase selector relay.

LESS important transmission lines are usually protected with directional overcurrent relays or induction disk-type impedance relays. On most of such subtransmission circuits there are stations where, in order to obtain selectivity, the relays have to be set for perhaps two seconds, and occasionally selectivity between two relays cannot be obtained at all because under one condition one relay has more current and under another condition the other has more. Better selectivity can be obtained with distance relays, but they are more expensive than overcurrent relays.

The modern high-speed induction-cylinder-type reactance relay is extremely accurate and easy to set. It is more expensive than either the overcurrent relay or the impedance relay of the induction-disk type, hence its use has generally been confined to high-voltage transmission lines. What is required for subtransmission lines is a relay with substantially the characteristics of the high-speed reactance relay at the price of the directional overcurrent relay. Although this is not yet literally possible, a very good compromise can be obtained by using one reactance relay, instead of the usual three, and a selector relay to connect it to the proper currents and potentials.

While, in general, stability is not the problem on subtransmission circuits that it is at the higher voltages, there are cases where it is desirable to obtain fast clearing times, such as on circuits between a large generating station and a load area; also, where a line may be burned down unless promptly cleared. In the arrangement to be described the selector relay operates in four cycles and the distance relay in one cycle for nearby faults making a total of 5 cycles on a 60 cycle system.

It is seldom that more than one of the distance relays in the three phases operates on a fault because only one of the line-to-line potentials is affected in line-to-line faults. In balanced three-phase faults all three relays may operate, but only one is necessary to effect tripping. Consequently, for less important transmission lines and those where one cycle relay operation is not required, it is permissible to use a single distance relay and to connect it to the faulted phases by a selector relay.

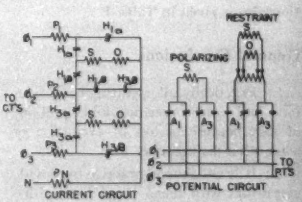
Compared with directional overcurrent relays for phase faults the new scheme is easier to apply and gives complete selectivity combined with high-speed tripping at only a moderate increase in cost. Compared with conventional distance relays the new scheme effects a saving in critical materials and labor, since one distance relay and an auxiliary relay replaces three distance relays. This in turn reduces investment, panel space, and maintenance.

Historical

In 1934 a paper[1] was presented before the Institute describing different methods of controlling distance relays with selector relays so that one set of distance relays could take care of both phase and ground faults or one relay could protect three phases against either phase or ground faults. Later 72 induction-disk-type reactance relays were installed, normally connected for phase faults, and with provision for switching to wye potentials, and so forth, for ground faults. A report of satisfactory operation was received, and twenty-four more were installed on the same system.

Selector relay schemes were widely used in Europe, but they did not become popular in this country. One reason for this may have been that the distance measurement with the selector schemes then available was not as accurate as with the full set of relays, particularly on ground faults; another may have been that the minimum time was about half a second. It is the purpose of this paper to describe a modern arrangement of distance and selector relays in which the same selectivity and accuracy is obtained as with a full set of distance relays and the minimum time is 0.08 second.

In one scheme a single distance relay protects against phase faults. In the other a single distance relay protects against ground faults. Both have been thoroughly tested in the laboratory, on the artificial transmission line, in life tests, and by staged faults on actual systems. Both are in service on lines in this country.



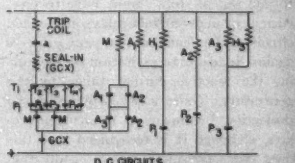


Figure 1. Schematic diagram for phase faults

$P_1P_2P_3P_N$—Overcurrent fault detectors in the three phases and residual circuit

$A_1A_2A_3$—Auxiliary relays controlled by $P_1P_2P_3$

H_1H_2—Current transfer relays. α and β refer to their two sets of transfer contacts

S and O—Starting and ohm units of the reactance relay

M—Relay for delaying tripping 0.025 second

$T_1T_2T_3T_N$—Targets indicating circuit involved in fault

Paper 43-92, recommended by the AIEE committees on power transmission and distribution for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21-25, 1943. Manuscript submitted April 8, 1943; made available for printing May 15, 1943.

L. J. AUDLIN is relay supervisor in the power control department of the Central New York Power Corporation, Syracuse, N. Y. A. R. VAN C. WARRINGTON is design engineer, relay section, switchgear department, General Electric Company, Philadelphia, Pa.

The kindness of the Duquesne Light Company and of the Central New York Power Corporation in arranging for the test was greatly appreciated. The engineering and operating staffs of the two companies are to be commended for their efficient planning and execution of the tests.

High-Speed Reactance Relay

The relay provides three zones of operation, giving the well-known stepped time-distance characteristic which has been described in previous papers. Faults up to 90 per cent of the distance to the next station are cleared instantaneously; faults in the neighborhood of the next station are cleared after a delay sufficient to allow the proper breaker at that station to open; more remote faults are cleared in a still longer time. These three zones are adjustable in distance by means of an internal tapped transformer; and all but the shortest range, which operates in about one cycle, are adjustable in time.

Upon the occurrence of a fault in the tripping direction the relay operation is initiated by a directional impedance unit called the starting unit. The zone is decided by the ohm unit, which measures the reactance of the line between the relay and the fault, and the time is controlled by a clockwork timer, self-wound by a d-c solenoid.

The starting and ohm units are of the induction-cylinder type which is well known for its efficiency and a steady torque. The ohm unit is accurate within plus or minus two per cent over a wide range of current and power factor. The use of reactance as a basis of distance measurement minimizes error caused by arc resistance which is particularly important in ground faults.

For phase faults the reactance relay is supplied with the potential between the faulted conductors and the vectorial difference of the current flowing in them. With this excitation the relay will measure the same distance for three-phase, phase-to-phase, and double-ground faults. For ground faults the reactance relay has the phase-to-neutral potential of the faulted conductor and the current in the conductor plus a predetermined portion of the residual current. With the proper amount of residual current the relay will measure substantially the same distance regardless of changes in system connections.

Protection Against Phase Faults

A high-speed reactance relay is controlled by a selector relay. Figure 2 shows the external appearance of these relays.

The operating characteristics of the reactance relay are the same as those of the standard *GCX* relay except that shorter lines can be protected because the potential circuit is not continuously energized and hence can be short-time rated.

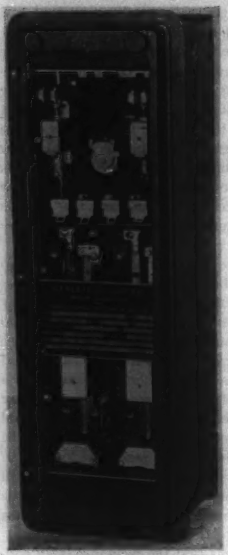


Figure 2a (left). Selector relay for phase faults

Figure 2b (right). Type GCX high-speed reactance relay

The selector relay contains two calibrated instantaneous overcurrent units (P_1 and P_3 in Figure 1) in phases 1 and 3, which detect the fault and determine the phases involved. These overcurrent units control auxiliary relays A_1 and A_3 respectively which apply the line-to-line potential between the faulted phases to the restraining coils and the quadrature potential to the polarizing coil of the reactance relay. They also energize the proper current transfer relay, H_1 or H_3, and set up the correct tripping circuits for target indication. There are two smaller overcurrent units, P_2 and P_N, in phase 2 and the residual circuit, which are for target indication. There are two current transfer units H_1 and H_3 which connect the current coils of the reactance relay to the current transformers of the faulted phases. The selector relay also contains a time-delay unit M which delays tripping slightly so as to ensure proper selection by the reactance relay unaffected by an external fault changing its character. There are four targets marked phase 1, phase 2, phase 3, and ground.

The currents and potentials supplied to the reactance relay are shown in Table I.

The overcurrent units are of standard design and the current transfer units have high-pressure overlapping contacts which ensure that the current-transformer circuit will never be opened.

Table I

Type of Fault	E Restraint (Ohm Unit and Starting Unit)	I	E Polarizing (Starting Unit)	X Measured*
ϕ_1–ϕ_2 or ϕ_1–ϕ_2–G	E_{12}	I_1-I_2	E_{31}	$2X_p$
ϕ_2–ϕ_3 or ϕ_1–ϕ_2–G	E_{23}	I_2-I_3	E_{12}	$2X_p$
ϕ_3–ϕ_1 or ϕ_1–ϕ_2–G	E_{31}	I_3-I_1	E_{23}	$2X_p$
ϕ_1–ϕ_2–ϕ_3	E_{12}	I_1-I_3	E_{31}	$2X_p$

* X_p is the positive sequence reactance.

Ground-Fault Protection

The relays are similar to those used for phase faults, but wye potentials are used, and residual current is supplied to the second current coil instead of minus the current from the next lagging phase. Residual current is also supplied from any parallel lines in order to compensate for mutual coupling.

The ground-reactance relay differs from the phase-reactance relay only in the addition of a capacitor to give the starting unit maximum torque with residual current 45 degrees lagging the residual potential. Figure 3 shows how the connections of the ground-selector relay differ from those of the phase-selector relay which was shown in Figure 1.

Type of Fault	E Restraint (Ohm Unit and Starting Unit)	I	X Measured
ϕ_1–G	E_1	I_1+KI_{res}	$2X_p$
ϕ_2–G	E_2	I_2+KI_{res}	$2X_p$
ϕ_3–G	E_3	I_3+KI_{res}	$2X_p$

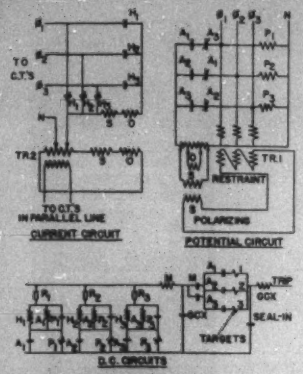


Figure 3. Schematic diagram for ground faults

$P_1P_2P_3$—Undervoltage fault detectors in the three phases

$A_1A_2A_3$—Auxiliary relays controlled by $P_1P_2P_3$

$H_1H_2H_3$—Current transfer relays

$R_1R_2R_3$—Resistors

TR 1—Wye-broken delta auxiliary potential transformer

TR 2—Residual auxiliary current transformer

Three undervoltage units energized with wye potential are used for detecting ground faults on systems grounded through impedance. Figure 5 shows how a single-phase ground fault on an impedance-grounded system displaces the neutral so that the faulted phase gets low voltage whereas the other two get above-normal voltage, so that the selection of the faulty phase is very definite. On solidly grounded systems either undervoltage or overcurrent fault detectors can be used, depending upon the distance from a grounding point.

The undervoltage units are set to drop out at 90 per cent of normal potential. The reactance relay is normally de-energized; when a fault occurs the undervoltage unit *P* in the faulted phase drops out energizing an auxiliary relay *A* and a current transfer relay *H*. The relay *A* seals around the contacts of *P* and applies the potential of that phase to the reactance relay as shown in Figure 3 while the transfer unit *H* connects the relay-current coils to the current transformer of the same phase, so that the relay is now ready to measure the distance to the fault. When the fault has been cleared and line voltage restored to normal, the *P* units pick up and short-circuit the coils of the *H* and *A* units so that they reset.

The reactance relay does not trip directly but through an auxiliary relay *M* with a slight time delay; this is in order to give the reactance relay a chance to reset if an external fault should change its character. For example, if an external single-phase fault should blow into a second phase, the reactance relay may close its contacts, because the additional current between the conductors may make the line reactance appear to be lower than the ohm unit setting. This condition will be very brief because the operation of the second current-transfer relay will by-pass the interphase current; the time-delay relay requires that the reactance-relay contacts remain closed for one cycle before it will trip the breaker; hence the reactance-relay contacts will reset before the auxiliary relay can pick up and trip. During this double-ground fault condition the selector relay supplied both current windings with residual current and the potential winding with the leading of the two wye potentials involved in the fault. This ensures underreaching on double-ground faults so that the relay acts only as a back-up for phase relays.

The current coils of the reactance relay are all double-wound. One winding is supplied with residual current and the other with phase current controlled by the phase selector relay. The restraining potential coils of the ohm unit and starting unit have phase-to-neutral potential controlled by the selector relay. The

Figure 4. Selector relay for ground faults

polarizing or directional potential coil of the starting unit has residual potential which is supplied by auxiliary potential transformers connected wye-broken delta. In order to obtain correct measurement the potential should be supplied by three potential transformers in wye-wye grounded on the high side.

Targets

The usual targets are provided in the reactance relay to indicate the zone or time of operation. In the selector relay for phase protection four targets are provided for the three phases and ground.

The selector relay for ground faults has three targets. A ground target is not necessary, because the relay does not work unless the fault involves ground.

Tests

The tests were of three kinds: laboratory tests, including life tests to check the effectiveness of the "switching"; tests on the artificial transmission line to check the sequence of operation and the accuracy of distance measurement; and, finally, natural and staged tests and operating experience on an actual transmission line.

The point of greatest interest for most engineers is the idea of switching the current circuit. In the standard reactance relay, the potential and d-c circuits have been switched from zone 1 to zone 2 con-

Table II

Test Number	Fault Location	Type	Fault	Location	Phase Targets	Zone Targets
1	Ilion	Solid	1–2–*G*	5% beyond zone 1 setting	1–2–*G*	2
2	Ilion	Solid	1–2–*G*	5% inside zone 1 setting	1–2–*G*	1
3	Ilion	Solid	2–3–*G*	5% inside zone 1 setting	2–3–*G*	1
4	Ilion	Solid	3–1–*G*	5% inside zone 1 setting	3–1–*G*	1
5	Ilion	Solid	3–1–*G*	5% beyond zone 1 setting	3–1–*G*	2
6	Ilion	Solid	1–*G*	5% inside zone 1 setting	—	—
7	Ilion	Solid	3–*G*	5% inside zone 1 setting	—	—
8	Ilion	Solid	1–2–3–*G*	5% inside zone 1 setting	1–2–3	1
9	Ilion	Solid	1–2–3–*G*	5% inside zone 1 setting (current reversed in relay)	—	—
10	Washington Street	Solid	1–2–3–*G*	On outgoing side of bus (current reversed in relay)	—	—
11	Washington Street	Solid	1–2–3–*G*	On outgoing side of bus	—	—

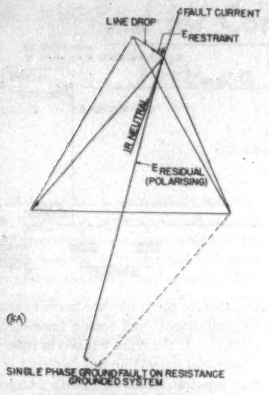


Figure 5. Vector diagram of ground fault

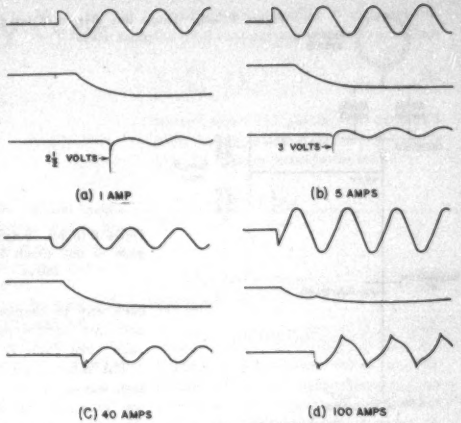


Figure 6. Oscillograms of current transfer relay operation

The top trace is the current in the winding of the current transformer. The middle trace is the current in the coil of the current transfer relay. The bottom trace is the voltage across the current windings of the reactance relay and the contacts of the current transfer relay

nections for the last eight years without trouble, and it is actually easier to switch current than potential because the current transformer will provide a high enough potential to break down an insulating film on the contacts. With contacts of adequate size, overlap, and pressure, switching current is no less reliable than switching potential, and the contacts require less maintenance.

(a). Laboratory Tests

Oscillograms (Figure 6) taken at 1, 5, 40, and 100 amperes showed smooth transition of current. The voltage across the contacts was negligible at the higher currents; at five amperes there was a peak of about three volts magnitude which lasted only about 0.00002 second. After a continuous life test of 5,000 operations at 100 amperes, the contacts were still in good shape; oscillograms showed some peaks up to 11 volts, but of less than one millisecond duration. A life test of 500 operations with zero overlap marred the contacts but did not interfere with their operation. A further life test with $^1/_{32}$-inch negative overlap, that is, break before make, caused pitting of the contacts, but no failure, although there was a large amount of energy in the arc because of 100 amperes flowing through $^1/_{32}$ inch of air. This was obviously worse than any possible condition of deteriorated adjustment, so it was felt that the design was very satisfactory.

In all these life tests, the circuit was arranged to close 100 amperes on the *a* contacts for three seconds and then to transfer back to the *b* contacts at three amperes for 15 seconds. These conditions are very much more severe than any service duty because of the heat that is accumulated in the contacts.

(b). Artificial Transmission-Line Tests

In these tests, the relay was applied to lines of different lengths, and the tap settings of the reactance relay for the borderline between zone 1 and zone 2 operation were checked for different conditions of generator and load to see if any variations in balance point occurred which could be blamed on the selector relay. In addition, tests were made in which the type of fault was changed (for instance from phase 1–ground to phase 1–phase 2–ground) to determine if, during the transition, any incorrect tripping would result from momentarily having the wrong potential or current on the distance measuring elements. Using all possible fault combinations it was impossible to cause incorrect operation.

(c). System Tests on Phase Relays

The reactance and selector relays for phase faults were installed last year on the Washington Street–Ilion line at the Washington Street substation on the 44-kv system of the Central New York Power Corporation. This circuit has a calculated resistance of 7.37 ohms and a calculated reactance of 10.75 ohms, which corresponds to 1.61 ohms secondary reactance. The relay measures $2X_p$ which is 3.22 ohms; zone 1 (instantaneous) was set to reach ten per cent short of Ilion, 2.86 ohms, and zone 2, 3.45 ohms. The time settings were one-half second and two seconds for zone 2 and zone 3.

There have been two faults on this circuit during electrical storms. The first case of trouble was a one-wire-to-ground fault approximately 90 per cent of the distance from Washington Street to Ilion. The relays did not operate on this disturbance, which was correct.

When the second fault occurred the relays operated and showed 1–2–3–*G* and zone 1 targets, indicating that a fault had probably started two-wire-to-ground and then involved the third phase. The

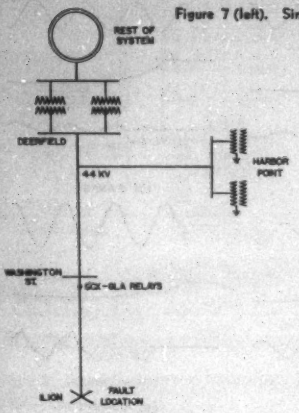


Figure 7 (left). Single line diagram of test circuit for phase relays

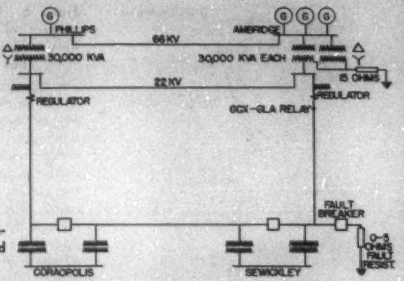


Figure 8 (right). Single line diagram of test circuit for ground relays

fault was approximately 25 per cent of the distance from Washington Street to Ilion. A simultaneous three-phase-to-ground fault would not show a *G* target, because the fault current would be practically balanced in the three phases and would give negligible residual current.

Several cases of trouble have occurred on other circuits in the next bus section or in the bus section back of the relay where fault current was reversed in the relay and the relay scheme functioned correctly; that is, did not operate.

For the purpose of the tests a portion of the 44-kv system was reconnected temporarily as in Figure 7. The short-circuit phase current was supplied by two 15,000-kva, 110,000 wye to 44,000 delta, transformer banks connected to the 110,000-volt system at the Deerfield substation in Utica. The calculated three-phase short circuit is 1,178 megavolt-amperes on the Deerfield 110-kv bus. Two grounding transformers, located at Harbor Point substation in Utica, supplied the ground current.

Solid faults were placed on the Washington Street–Ilion line between the line disconnect and the oil circuit-breaker at Ilion with the circuit de-energized. The faults were initiated on the system from the Washington Street 44,000-volt bus by closing the circuit breaker at the Washington end. The 44,000/110-volt potential transformers connected to this bus supplied potential to the relays and a *PM*-13 oscillograph.

Instead of moving the fault location the relay setting was changed five per cent each way to simulate faults just inside and just outside of the instantaneous zone. See Table II.

The relay potential in the last two tests was so low that indeterminate action was expected, but actually, in test 11 the relay moved slowly toward the tripping contacts and would probably have tripped if the back-up relay had not tripped first.

(d). System Tests on Ground Relays

The relays were tested on the 22-kv system of the Duquesne Light Company near Pittsburgh. The principal purpose of this was to determine the effect of load current and ground resistance on the accuracy of ground-distance relays on a system grounded through a resistance of roughly one ohm per kilovolt. The results of the tests will be published later when complete and edited. The present description of the tests will be limited to reference to the operation of the selector relay.

The tests were made at the Ambridge station on the line to Sewickly where the faults were applied as shown in Figure 8. Sewickly was also fed from Phillips in the other direction via Coraopolis. Between each source of power and the fault was a voltage regulator so that the phase and magnitude of the current transfer could be accurately controlled over 360 degrees range. The resistance of the faults at Sewickly was varied between zero and five ohms, and the balance points were found for various conditions to determine the effect of load in combination with fault resistance.

Oscillograms were taken of the phase current, the residual current, the phase potential, the residual potential, the current and potential supplied to the reactance relay, and the tap current. For each condition, the setting of the relay was calculated for the borderline between zone 1 (instantaneous) and zone 2 (intermediate time). If the relay tripped in zone 1, the potential tap setting was increased one or two taps until it showed a zone 2 target, and the balance point was therefore between the tap which gave a zone 1 target and the tap that gave a zone 2 target.

The balance point was checked with the selector operating normally and with its contacts held manually in the positions they would assume during the fault. In no case was there any difference between the balance points.

Conclusions

The combination of selector relay and distance relay thus provides the accuracy, selectivity, and ease of application of the *GCX* relay and for the first time makes distance relay protection economical for subtransmission lines where the expense of a full set of distance relays is not justified, and five-cycle operation is satisfactory.

References

1. Sur l'Emploi des Relais d'Impedance Pour la Protection des Lignes Aeriennes Contre les Mises a la Terre, Jean Fallou. *Bulletin* de la Société Française des Electriciens, series 4, volume 10, number 101, January 1930, pages 82–94.

2. Die Distanzschutz-Schaltungen, M. Walter. *Elektrizitatswirtschaft*, April 30, 1932, pages 172–6, and May 15, 1932, pages 199–202.

3. Control of Distance Relay Potential Connections, A. R. van C. Warrington. AIEE Transactions, volume 53, January section, 1934, pages 206–13.

4. High-Speed Distance Relays, G. Stark, F. Frohlich. *AEG Mitteilungen*, January 1934, pages 27–31 (in German).

5. New Developments in Distance Relay Connections, Eric T. Gross. *Electrotechnik und Maschinenbau*, volume 52, January, 1934, page 597.

6. What Is SD Protection? *AEG Progress*, Berlin, volume 2, 1939, pages 40–43.

7. Review of Distance Relay Protection, Gerhard Walther. *Elektrotechnische Zeitschrift*, Berlin, 1940, volume 4, number 85.

A Method for Correlating Duty-Cycle Tests on Solenoids

J. E. RYAN
NONMEMBER AIEE

A SOLENOID is customarily rated in terms of the minimum pull exerted at any point within its rated stroke when a certain fraction of its nominal voltage is impressed on the coil. Furthermore, when full nominal voltage is applied continuously, the temperature rise of the coil must not exceed a certain value, depending on the class of insulation used and the maximum ambient temperature.

In many applications, however, solenoids are not energized continuously but perform their function at more or less regular intervals with rest periods between operations. With a-c solenoids operating on such a duty cycle, two influences are present, one tending to decrease the heating, the other tending to increase it. Because it is energized only a fraction of the time, the solenoid, with its plunger seated, develops less heat per second than when continuously energized. On the other hand, the power input during the brief time when the plunger is in motion is many times greater than when the latter is seated. The total energy thus expended at each operation depends on the load and the stroke. Thus, with a given load and stroke, it is possible to operate the solenoid at such intervals that the additional energy expended during the pickup periods exactly compensates for the reduced heating in the seated position. The coil temperature rise will then be the same as in the continuously energized case, and the solenoid may be considered as operating at its full duty-cycle rating for the particular load, stroke, and per cent time energized in question.

The relations between load, stroke, per cent time energized, operations per unit time, and temperature rise are best determined experimentally, but the procedure is tedious if the operation frequency must be varied by trial on each test until the allowable temperature rise is reached. Moreover, the results are then applicable only in cases where that particular temperature rise limit is prescribed. With the test and correlation method hereinafter described, a minimum of tests provide data from which the temperature rise under any combination of the operating variables may be predicted.

The analysis underlying the correlation method is given first, followed by a description of the test and correlation procedure. The symbols used are defined in the appendix.

Paper 43-108, recommended by the AIEE committee on basic sciences for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21-25, 1943. Manuscript submitted April 28, 1943; made available for printing May 19, 1943.

J. E. RYAN is with the General Electric Company, Schenectady, N. Y.

Analysis

The static pull curve of a typical a-c solenoid is shown in Figure 1. If the plunger starts its closing motion at a gap s, the kinetic energy possessed by the moving parts of the solenoid and its load at gap x will be

$$E_x = \int_x^s (f-L)dx = \frac{Wv^2}{2g} \tag{1}$$

whence

$$v = -\sqrt{\frac{2gE_x}{W}} \tag{2}$$

Since

$$dt = \frac{dx}{v}, \qquad T = \int_s^s \frac{dx}{v} = \sqrt{\frac{W}{2g}} \int_0^s \frac{dx}{\sqrt{E_x}} \tag{3}$$

which may be written as

$$T = \sqrt{W} F_1(L, s, x) \tag{4}$$

The heat input to the coil during the plunger travel is

$$H_c = \int_0^T P_c dt \tag{5}$$

Figure 2 shows a typical relation between P_c and x, taken from static tests. Actually, when the plunger moves rapidly, P_c may also be a function of those factors which affect the speed, namely, L, W, s, x. Then, using equation 4 in 5

$$H_c(L, W, s) = \sqrt{W} \int_s^s P_c(L, W, s, x) dF_1 \times (L, x, s) \tag{6}$$

where the integration limits are on the variable x. Hence

$$H_c(L, W, s) = \sqrt{W} F_2(L, W, s) \tag{7}$$

Similarly

$$H_t(L, W, s) = \sqrt{W} F_3(L, W, s) \tag{8}$$

During one operation of the solenoid, the total heat produced in the coil is then

$$H_c + \left(\frac{A}{N} - T\right) P_{cs} \tag{9}$$

where $(A/N-T)P_{cs}$ is the heat produced while in the seated position. It follows that the average power in the coil is

$$\overline{P}_c = \frac{H_c + \left(\frac{A}{N} - T\right) P_{cs}}{\left(\frac{1}{N}\right)} = (H_c - P_{cs}T)N + P_{cs}A \tag{10}$$

Similarly,

$$\overline{P}_t = (H_t - P_{ts}T)N + P_{ts}A \tag{11}$$

These average power values may be related to the coil temperature rise by considering the equivalent thermal circuit of the solenoid shown in Figure 3. If the thermal resistances are assumed independent of temperature or temperature difference, it is evident that the temperature at 0, representing the average condition in the coil, will be a linear function of $\overline{P}_c$ and $\overline{P}_t$ of the form

$$\theta = F_4(R_{cs}, R_{ct}, R_{ts})\overline{P}_c + F_5(R_{cs}, R_{ct}, R_{ts})\overline{P}_t \tag{12}$$

Actually, the various R's are not strictly constant even during a single operation of the solenoid. When the plunger is extended, the inner surfaces of the coil and the plunger itself are more effectively cooled than when the latter is seated. If it can be assumed that the heat transfer through each of the resistances is improved by a factor $(1+K_1S)$ whenever the plunger is extended, the average resistances for a complete operation cycle are:

$$R_{cs} = \frac{R_{cs}'}{1+K_1S(1-A)}; \quad R_{ct} = \frac{R_{ct}'}{1+K_1S(1-A)}; \quad R_{ts} = \frac{R_{ts}'}{1+K_1S(1-A)} \tag{13}$$

Hence equation 12 becomes

$$[1+K_1S(1-A)]\theta = F_4(R_{cs}', R_{ct}', R_{ts}')\overline{P}_c + F_5(R_{cs}', R_{ct}', R_{ts}')\overline{P}_t = k_c\overline{P}_c + k_t\overline{P}_t \tag{14}$$

Substituting equations 10 and 11 into 14 there results

$$[1+K_1S(1-A)]\theta = [k_c(H_c - P_{cs}T) + k_t(H_t - P_{ts}T)]N + [k_cP_{cs} + k_tP_{ts}]A$$

or

$$\theta = \frac{F_6(L, W, s)N + K_2A}{1+K_1S(1-A)} \tag{15}$$

K_1, F_6, and K_2 may be determined as described in "Determination of Constants." Having done this, θ may be

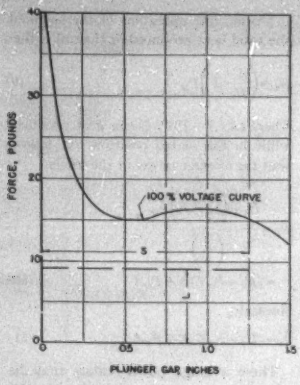


Figure 1. Pull curve of a typical a-c solenoid

evaluated from equation 15 for any combination of L, W, S, A, and N.

Determination of Constants

(A). K_2

The solenoid is energized continuously at full voltage until steady temperature rise is attained. According to equation 15, the coil rise θ is then

$$\theta = K_2 A = K_2 \qquad (16)$$

since $A = 1.0$ and $N = 0$

(B). F_6 AND K_1

Equation 15 may be written in the form

$$[1+K_1S(1-A)]\theta - K_2A = F_6(L, W, s)N \quad (17)$$

which can be of the straight-line form

$$y = mx$$

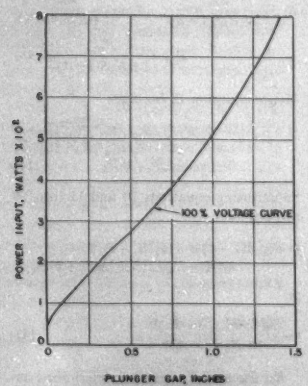


Figure 2. Power input versus plunger gap for a typical a-c solenoid

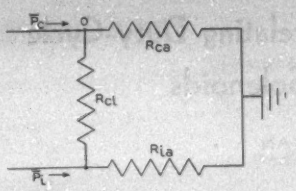


Figure 3. Thermal circuit of an a-c solenoid

if

$$y = [1+K_1S(1-A)]\theta - K_2A$$
$$x = N$$
$$m = F_6(L, W, s) \qquad (18)$$

Thus a plot of $[1+K_1S(1-A)]\theta - K_2A$ versus N for experimental data taken at a fixed load and stroke should be a straight line of slope F_6 passing through origin. Such a plot is shown in Figure 4 with lines corresponding to three different values of F_6.

In obtaining the data for any one line the solenoid is operated at full voltage with a certain load and stroke. For each of several values of A, tests are run at different cycling speeds until steady temperatures are reached. Then with K_2 definitely known from the continuous heat run, and K_1 tentatively assumed equal to zero, y may be worked out and plotted against N.

If zero is the correct value of K_1, the data for different values of A will all have the same slope; if $K_1 = 0$ is too low, the points for the lesser values of A will describe a line of slightly lower slope than the points for the higher values. At this juncture, various values of K_1 should be tried (usually less than 0.25) until divergence in the data is eliminated. Once determined, this same value of K_1 should cause data taken at other strokes and loads to correlate equally satisfactorily.

Tests made at convenient fractions of full load are plotted in the manner of Figure 4. Thus F_6 becomes known, as a function of stroke, for each of several loads. Figure 5 shows the final arrangement of the data for an all-weight load.

Adaptation to Mixed Weight and Spring Loads

With mixed weight and spring loads, the F_6 values will be less than those of Figure 4. To determine them accurately, it would be necessary to run a complete set of tests for each of several spring-weight combinations, but a good approximation can be deduced from the tests with all-weight loads as follows: Equation 4 shows the closing time to be proportional to $\sqrt{W}$ for a given total load and stroke. This, in turn, makes H_c and H_t

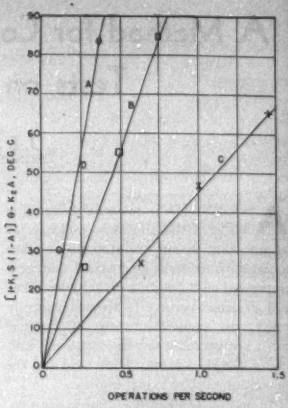


Figure 4. Data plot for determining the load-stroke function, F_6, of an a-c solenoid

A—100 per cent stroke
B— 70 per cent stroke
C— 40 per cent stroke
100 per cent rated load

vary substantially as $\sqrt{W}$. Following this through equations 10 and 11 to 15, it will be seen that F_6 is also proportional to $\sqrt{W}$. Thus for a mixed load, the F_6 for an all-weight load of the same magnitude should be multiplied by $\sqrt{W/L}$ to obtain a proper value for use in equation 15.

Advantages of the Method

It has been shown that K_2 is determined from a single preliminary heat run and

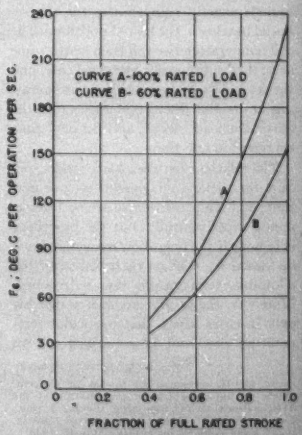


Figure 5. Load-stroke function, F_6, of an a-c solenoid with a purely weight load

that a proper K_1 may be found from a few duty-cycle runs taken at various values of A and N while holding the load and stroke constant. Thereafter, one duty-cycle heat run will suffice to determine F_0 for any one combination of L, W, and S, since a single experimental point and the origin can locate a line in Figure 4. However, several points are desirable for each line in Figure 4 to minimize experimental error. Even so, the number of tests required to completely cover all possible combinations of L, W, S, A, and N is greatly reduced by the use of this correlation method. Furthermore, experimental errors are readily detected, and the extrapolation of the data beyond the scope of the investigation is made more certain.

Applications Other Than A-C Solenoids

D-c solenoids in which a relatively large current is allowed to flow for a brief time during the pickup period are often used to increase the work output for a given size. As the plunger is seated, a cutout switch or relay operates to insert resistance and reduce the current to a suitable continuous value. Since, as with a-c solenoids, it is difficult to compute the energy input during the closing period, the correlation method of this paper is useful in organizing the duty-cycle-heating data.

In general, the method may be applied to any electrical device subjected to regular heating cycles so long as the cycling period is substantially less than the thermal time constant of the device. It is particularly useful when there is a complex transient heating effect in each cycle.

Appendix

Symbols

x = instantaneous plunger gap, inches
s = total plunger stroke, inches
S = fraction of full rated stroke
f = instantaneous magnetic force parallel to plunger travel, pounds
L = total load opposing magnetic force, pounds
W = equivalent weight of moving parts, pounds*
v = velocity of plunger, inches per second
g = acceleration of gravity, inches per second squared
E = kinetic energy, inch-pounds
t = time from start of plunger motion, seconds
T = total plunger motion time, seconds
P = power input, watts
H = energy input during closing period, watt-seconds
A = fraction of time solenoid is energized
N = operations per second
R = heat flow resistance, degrees C per watt
θ = coil temperature rise above ambient, degrees C
K, k denote constants.
F denotes a function, the independent variables of which are given in the parentheses following the symbol.
Bars above quantities indicate average values.
Prime superscripts on R's refer to thermal resistances existing when the plunger is seated.

SUBSCRIPTS

x refers to instantaneous position of plunger.
s refers to sealed position of plunger.
c refers to coil.
i refers to iron.
ca refers to coil to ambient air.
ci refers to coil to iron.
ia refers to iron to ambient air.

* An element of mass $\Delta M'$ in an associated mechanism may be represented by an equivalent mass ΔM attached directly to the plunger if

$$\Delta M = \Delta M' \left(\frac{v'}{v}\right)^2$$

where v' is the velocity of $\Delta M'$ when the plunger velocity is v.

A Simple Method for the Determination of Bushing-Current-Transformer Characteristics

S. D. MORETON
ASSOCIATE AIEE

Synopsis: Now that excitation characteristics are being made available to the application engineer, it has become increasingly important that a simple accurate calculation method be used to determine the errors. "Inphase addition" has all the advantages of simplicity, and, under careful analysis, it is apparent that over the normal ranges involved, the more complicated procedure of vector addition is not warranted. This simple method has been extended to cover complete curve drawing from only one calculation by a graphical process.

IN the past, characteristics of bushing current transformers have been presented in the form of curves of true ratio versus primary current for a variety of different burdens and power factors. Such curves were obtained by tests on the actual transformers and were the only data available to the application engineer. The art of calculating current-transformer characteristics from excitation curve data has been known for some time;[1,2] only recently, however, has popular attention been focused upon it as a method[3,4] for determining the transformer errors of a particular application. With this in mind, the American Standards Association standards have been written to foster a calculation method,[5] although no specific method was decided upon.

It has been realized that such a radical change in application procedure might well result in difficulties unless the method was reasonably easy to use, and it has, therefore, been suggested that the errors introduced by the relatively simple method of inphase addition be investigated more fully. The conclusion was reached that this method was the practical answer. These errors are best shown graphically, as in Figure 1, which gives a comparison of calculated results for three of the ratios of a 600/5 multiratio bushing current transformer with a two-ohm burden at 90 per cent power factor and 50 per cent power factor, as well as inphase addition. It is immediately apparent that the errors introduced by disregarding the angular difference between the secondary current and the exciting current are small for the normal range of relay burden power factors.

Conclusion

When all the variable factors are taken into consideration, as discussed under "Accuracy Factors," it is evident that the errors introduced by inphase addition are a relatively small part of the total pos-

Paper 43-110, recommended by the AIEE committees on protective devices and instruments and measurements for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21-25, 1943. Manuscript submitted April 19, 1943; made available for printing May 18, 1943.

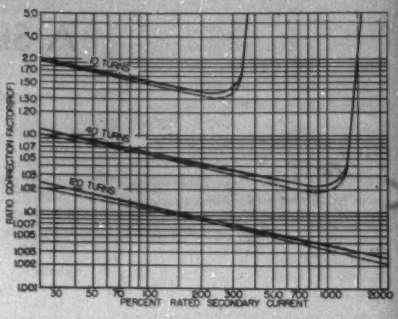
S. D. MORETON is engineer in the relay section of the General Electric Company, Philadelphia, Pa.

The author wishes to acknowledge the assistance of his associates for their constructive criticism, in particular, W. F. Skeats for his comments on the mathematical proof of the graphical method and his suggestions for a simplified presentation of the primary current.

sible variation, and thus, from the standpoint of the application engineer, inphase addition is justifiable for the normal range of burden power factors. This is particularly evident by a comparison of Figures 1 and 8.

Figure 1. Calculated ratio characteristics, two ohm burden

——— Inphase addition
— . — 90 per cent power factor
— — — 50 per cent power factor



Calculating Theory

Basically, the relationship between secondary ampere turns, exciting ampere turns, and primary ampere turns is a vectorial one, where the calculations are based on the equivalent circuit of Figure 2. The most time-consuming part of the calculations is the vector addition, whether it is performed mathematically, graphically, or by vector charts. By considering this vector relationship as a scalar relationship much of the work is avoided.

Calculating Procedure for Determining Ratio Correction Factor

The calculation procedure for inphase addition is based on the equivalent circuit of Figure 3, with steps and formulas as follows:

1. Compute the necessary secondary voltage to force the desired secondary current through the total burden, as: $E=IZ$.

2. Find the secondary exciting current required to produce this secondary voltage from the excitation curve, see Figure 4.

3. Add this secondary exciting current arithmetically to the secondary current and multiply by the number of secondary turns to obtain the primary current, as: $I_p=N(I_s+I_e)$.

The ratio correction factor (RCF) may be defined as the ratio of primary ampere turns to secondary ampere turns. In a bushing current transformer, the primary winding has one turn, therefore:

$$RCF=\frac{I_p}{NI_s} \tag{4}$$

$$RCF=\frac{N(I_s+I_e)}{NI_s}=1+I_e/I_s \tag{5}$$

and this may be found without passing through step 3.

Calculating Procedure for Determining Phase Angle β

In those applications that involve the comparison of two currents or a current and a voltage, it might be desirable to determine the phase-angle error of the current transformer. It may be found by an extension of the method of inphase addition and by the use of the phase-angle chart, Figure 5. Excitation characteristics are required that give not only the total exciting current but also the lagging excitation phase angle between the exciting current and the secondary voltage. Figure 6 is typical of this type data and is presented on a per-turn basis.

The chart is entered at a per-unit exciting current, I_e/I_s, of equation 5, which could be rewritten as:

$$RCF-1=I_e/I_s \tag{6}$$

The phase-angle error is read off directly, using the curve that corresponds to the "difference angle," equal to the burden phase angle minus the excitation phase angle ($\theta_s-\alpha_e$). The phase-angle error is positive when the difference angle is positive.

Accuracy Factors

Factors which influence the accuracy of the calculated results are variations of excitation characteristics of the current transformer from the typical curve values and variations in the magnitude of the burden.

The excitation requirements of electrical iron are not only a function of the size and shape of the core but also a function of the amount and kind of impurities, the type of rolling process used, the annealing temperature and subsequent cooling, as well as the previous magnetic history. Some of these factors are very difficult to control, with the result that the final characteristic, as published by the manufacturer in the form of a typical excitation curve, is, of necessity, only an average curve. All of the factors lumped together and controlled with the usual manufacturing tolerances can well result in a variation as great as plus or minus 50 per cent in the total exciting current at any one particular flux density for various lots of iron. By more rigid control and selective choice of the iron by sampling processes, this can be reduced to plus or minus 25 per cent; see Figure 7 for a typical band curve. Even this variation would seem to be intolerable, were it not for the fact that this represents a variation of the ratio error of the transformer and not of the true ratio. In the majority of applications, where the maximum desirable RCF is less than 1.1, and where the transformer is operating below the knee of the excitation curve, the maximum possible variation will be plus or minus 25 per cent of this ten per cent error, or plus or minus 2.5 per cent in the RCF; see Figure 8 for a typical band curve.

The use of a calculating method for the determination of bushing-current-transformer characteristics requires a knowledge of the magnitude of the burden which, in most instances, consists of relays that have iron cores, and thus have

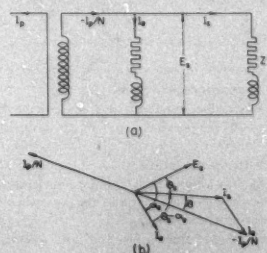


Figure 2
(a). Exact equivalent circuit
(b). Vector diagram of (a)

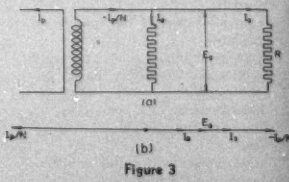


Figure 3
(a). Approximate equivalent circuit
(b). Scalar diagram of (a)

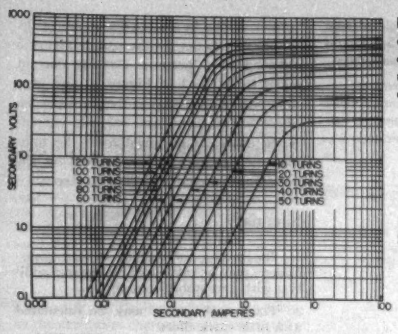


Figure 4 (left). Secondary excitation characteristic, 600/5 multiratio bushing current transformer

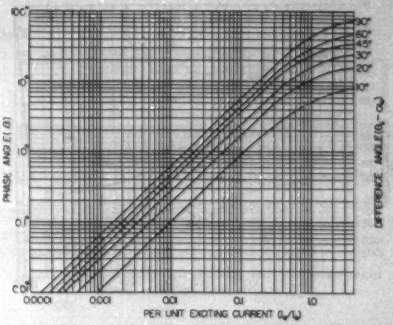


Figure 5 (right). Phase-angle error chart

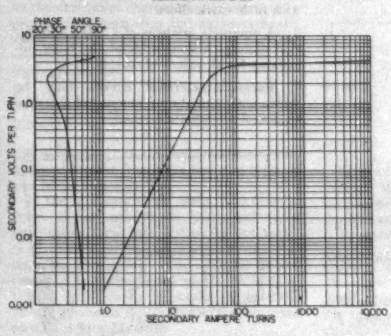


Figure 6 (left). Excitation characteristic

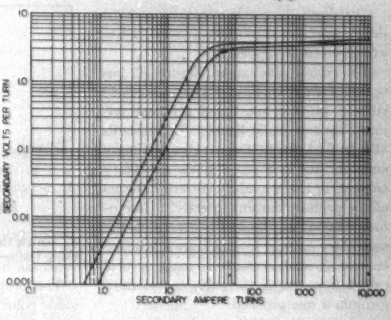


Figure 7 (right). Band-excitation characteristic

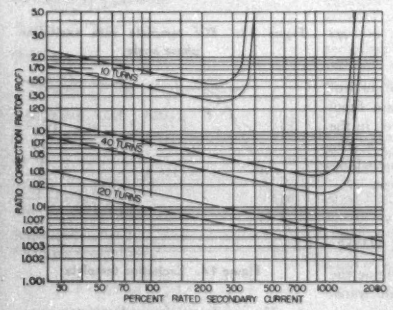


Figure 8 (left). Band-ratio characteristic on three ratios of a 600/5 multiratio transformer

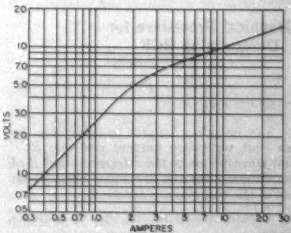


Figure 9 (right). Burden characteristic of time overcurrent relay on 1.5 ampere tap

inherently nonlinear impedances. Fortunately, the majority of relays have magnetic circuits which contain series air gaps so that the main part of the exciting current is required to establish the air-gap flux, and thus, large variations in exciting current of the iron core present only small variations in burden between units. Therefore, relays have relatively constant burden characteristics up to the point of iron saturation. Beyond this point, the reactance component of the burden is inversely proportional, approximately, to the current so that the current transformer will hold up to a higher value of primary current if burden saturation occurs before current transformer saturation. Typical burden values of relays are published by the manufacturer and are usually measured at the pickup current of the relay. If they are of the type that depends upon saturation to obtain its characteristics, such as a time overcurrent relay, the application engineer would require burden characteristics, such as shown in Figure 9, to make a thorough analysis. Thus, it seems inevitable that as the art of calculation becomes more widespread, the application engineer will require more complete information; see Figure 10 for a calculated *RCF* curve, based on composite characteristics of the overcurrent relay of Figure 9 and the transformer shown in Figure 4.

Graphical Method

When the ratio errors are desired for a range of primary current values for a multiratio transformer, the labor at calculation becomes tremendous, even with the simplification of inphase addition. To reduce this work, a graphical method has been developed, which eliminates the point-by-point method of curve drawing and permits a complete characteristic to be drawn from one calculation by the use of a master template, Figure 11.

Note that the shape of this template is a function of the type of iron and the size of the log-log co-ordinate paper only.

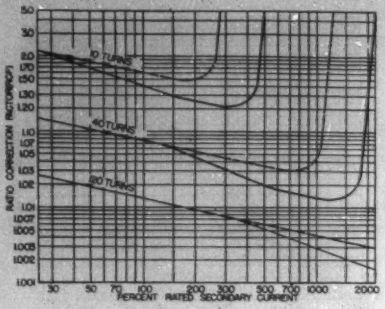


Figure 10. Calculated ratio characteristic, 600/5 multiratio bushing current transformer

——— 2.5 ohm burden

——— time overcurrent relay burden on 1.5 ampere tap (2.5 ohms at pickup)

The derivation of the method and the development of the shape of the template are given in the appendix.

The co-ordinate paper, Figure 12, has scales of *RCF* versus per cent secondary current (dotted lines) and per cent primary current (solid lines). Thus, one is able to find the *RCF* for a given primary current, the *RCF* for a given secondary current, or the secondary current in terms of the primary current directly. Heretofore, when it was desired to determine the secondary current from a known primary current, it was necessary to make several calculations, using the ratio curves until formula 4 was satisfied.

Graphical Procedure for Determining RCF

The calculation procedure for this graphical method is:

1. Use formulas 7 and 8 to determine the per cent secondary current and the *RCF* that corresponds to the reference point *P* of the template for the particular burden and tap of the transformer involved.

2. Locate this point on the co-ordinate paper.

3. Set the template with its reference point on the corresponding point of the co-ordinate paper and line it up horizontally.

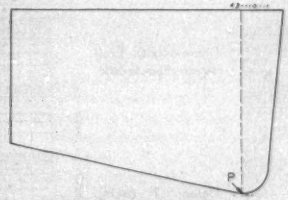


Figure 11. *RCF* template

4. Draw the complete characteristic curve, using the template as a guide.

The formulas required to determine this guide point of maximum permeability, *P*, are:

$$\%I_s = C(N/Z) \qquad (7)$$

$$RCF = 1 + D/(N\%I_s) \qquad (8)$$

where *C* and *D* are constants of the particular transformer involved and are functions of the shape and type of iron in the core, as well as the frequency. The constants *C* and *D* may be determined directly from the excitation curve.

Graphical Procedure for Determining Phase-Angle Errors

Where it is desirable to determine the phase-angle error of the current transformer, it may be obtained as a part of the graphical process by the use of Figure 5 entering at a per-unit exciting current equal to *RCF*−1 of Figure 12 and at a difference angle equal to the total burden phase angle minus the exciting current phase angle, as obtained from the template of Figure 13 when located on the co-ordinate paper according to step 3.

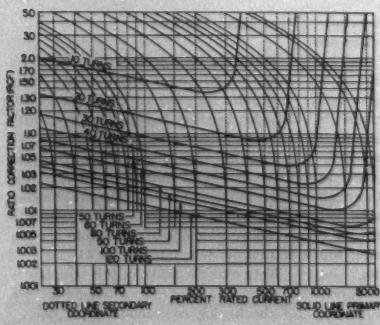


Figure 12. Calculated ratio characteristic, 600/5 multiratio bushing current transformer

Summary

1. Ratio errors of bushing current transformers may be calculated by inphase addition with acceptable accuracy.

2. Phase-angle errors may be calculated with little extra effort.

3. A complete analysis of a relay application requires a knowledge of the relay impedance for all values of current.

4. Ratio-characteristic curves may be drawn with a minimum amount of labor by the use of a template method.

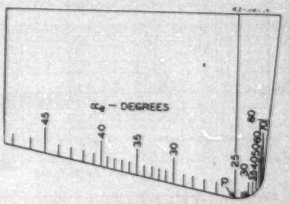


Figure 13. *RCF* template with excitation phase angle

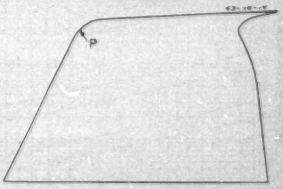


Figure 14. Excitation template

5. The use of special co-ordinate paper presents an ideal way to give ratio characteristics.

Appendix

Graphical Theory

Excitation Curve

Fundamentally the theory is based on the fact that the a-c excitation characteristics of electrical iron may be expressed mathematically as:

$$NI_e/l = f_1(E/NA, f) = f_1\left(\frac{I_eZ}{NA}, f\right) \qquad (9)$$

or

$$NI_e/l = f_2\left(\frac{E}{NA/f}\right) = f_2\left(\frac{I_eZ}{NA}\right) \qquad (10)$$

for any one particular frequency. This equation is in the form of:

$$P_g = f(Q_s) \tag{11}$$

and hence, if plotted on log-log paper with the exciting current as abscissa and the secondary voltage as ordinate, it represents a family of curves all of which have the same shape. Consequently one template, Figure 14, whose shape is determined solely by the magnetic properties of the iron and the co-ordinate paper can be used as a guide for drawing all curves of the family if one reference point, P, is marked on the template and is specified for each curve. It is convenient to select this reference point at an excitation corresponding to maximum permeability of the iron, which is the point on the excitation characteristic that is tangent to a 45-degree line and has an ordinate value of J and an abscissa value of K. The co-ordinates of the reference point on the log-log paper are:

$$E = JNA \tag{12}$$

$$I_e = KI/N \tag{13}$$

The constants J and K are functions of the primary-current frequency and the type of iron in the core only.

If the template is set with its reference point on the co-ordinate point and it is lined up with the axis, curves for any value of secondary turns may be drawn with the template as a guide. The ordinate of the template is proportional to the secondary voltage and from an inspection of equation 10 it is apparent that it is also proportional to the flux density since

$$E/NA = 4.44 B_{max.} f \times 10^{-8} \tag{14}$$

RCF Curves

Formula 10 may be expressed as:

$$\left(\frac{NI_e}{l}\right)\frac{NA}{ZI_s} = \frac{NA}{ZI_s} f_2\left(\frac{ZI_s}{NA}\right) \tag{15}$$

or

$$\frac{N^2A}{lZ}\frac{I_e}{I_s} = f_3\left(\frac{ZI_s}{NA}\right) \tag{16}$$

Substituting for I_e/I_s from equation 6 the following is obtained:

$$\frac{N^2A}{lZ}(RCF-1) = f_4\left(\frac{ZI_s}{NA}\right) = f_4\left(\frac{E}{NA}\right) \tag{17}$$

Equation 17 is also of the form of equation 11 and consequently represents a family of curves, when drawn on log-log paper, having scales of $(RCF-1)$ versus I_s, all of which can be drawn using a single template as a guide by setting the reference point, P, of the template, Figure 11, on the co-ordinates given by equations 12 and 13. It will be found more convenient to use equation 12 combined with equation 1 as:

$$I_e = \frac{JNA}{Z} \tag{18}$$

and equation 13 combined with equation 6 as:

$$RCF-1 = \frac{I_s}{I_e} = \frac{Kl}{NI_s} \tag{19}$$

Equations 18 and 19 can be converted to read in terms of per cent secondary current, $\%I_s$ (based on five amperes as 100 per cent) as:

$$\%I_s = \frac{20JNA}{Z} = C\frac{N}{Z} \tag{20}$$

$$RCF-1 = \frac{20Kl}{N\%I_s} = D/N\%I_s \tag{21}$$

where

$$C = 20JA \tag{22}$$

$$D = 20Kl \tag{23}$$

Here again it should be noted that the shape of the template of equation 17 is a function solely of the magnetic properties of the iron and the co-ordinate paper.

To convert this curve of $(RCF-1)$ versus per cent secondary current, the dotted co-ordinate lines of Figure 12, to $(RCF-1)$ versus per cent primary current it has been found most convenient to operate on the per cent secondary current scale itself by equation 6, where I_e/I_s represents the ratio error in per-unit values. Thus every co-ordinate value of $(RCF-1)$ and per cent secondary current has a corresponding co-ordinate value of $(RCF-1)$ and per cent primary current according to the equation:

$$\%I_p = 100(RCF-1) + \%I_s \tag{24}$$

which gives the resulting per cent primary current scale of solid co-ordinate lines in Figure 12.

For convenience in reading the numbers of the $(RCF-1)$ or ordinate scale they may be written as $(RCF-1)+1$ or RCF without changing either the shape of the template or the shape of the co-ordinates since equation 4 can be expressed as:

$$RCF = \%I_p/\%I_s \tag{25}$$

which is equivalent to equation 24.

Phase-Angle Curves

The abscissa of the RCF template is proportional to secondary voltage by equation 17, it is therefore proportional to the flux density by equation 14, and thus it is also proportional to the excitation phase angle of the iron, see Figure 6. Therefore the RCF template may be marked off in degrees of phase angle of the exciting current as in Figure 13, where the markings on the template are a function of the type of iron and the frequency only. The phase-angle error can be determined most easily by the use of a simplification of the vector charts following the procedure outlined earlier.

Glossary

E—Induced secondary voltage.
N—Number of secondary turns.
A—Cross-sectional area of magnetic circuit.
l—Mean length of magnetic circuit.
I_s—Secondary current.
$\%I_s$—Secondary current in per cent based on five amperes ($\%I_s = 20I_s$).
Z—Total secondary burden.
I_e—Excitation current based on secondary.
I_p—Primary current.
$\%I_p$—Primary current in per cent based on tap and five amperes in secondary circuit.
θ_z—Phase angle of total secondary burden Z.
α_e—Phase angle of exciting current.
β—Phase angle error of current transformer.
f—Frequency of supply in cycles per second.
$B_{max.}$—Crest flux density in the core.

References

1. A Study of the Current Transformer With Particular Reference to Core Losses, P. G. Agnew. *Bulletin*, Bureau of Standards, volume 7, 1911, pages 423–74.

2. Papers on Current Transformers, H. W. Price, C. K. Duff. *Bulletin 2*, University of Toronto, 1921.

3. A Proposed Method for the Determination of Current-Transformer Errors, G. Camilli, R. L. VanBroeck. AIEE Transactions, volume 59, 1940, September section, pages 547–50.

4. Overcurrent Performance of Bushing-Type Current Transformers, C. A. Woods, Jr., S. A. Bottonari. AIEE Transactions, volume 59, 1940, September section, pages 554–60.

5. Current- and Potential-Transformer Standardization, AIEE current transformer subcommittee of the committee on protective devices. AIEE Transactions, volume 62, 1942, September section, pages 698–706.

6. Current-Transformer Performance Based on Admittance-Vector Locus, A. C. Schwager. AIEE Transactions, volume 61, 1942, January section, pages 26–30.

Report on Application of Lightning Protective Devices in Wartime

AIEE LIGHTNING ARRESTER SUBCOMMITTEE

Preface: The present war emergency requires that the maximum use be made of existing equipment and systems and that a minimum of critical material be used for new equipment.

This publication and other guides and reports in this series have been prepared for the information of users during the war emergency. Upon termination of the war emergency they will be reconsidered by the standards committee and the committees which prepared them, and will be approved, revised for normal use, or rescinded.

This procedure is being followed in preference to the preparation of special emergency standards which might involve redesigning and drastic changes in manufacturing practices. These guides will accomplish the maximum conservation of critical materials, since they provide for the maximum use of existing equipment and systems, as well as new equipment, without changing the fundamental basis on which the present standards have been prepared.

I. Purpose and Scope

THE object of this report is to show how critical materials can be conserved in the application and use of lightning arresters to meet the wartime requirements of our country. This objective may be accomplished in two ways:

1. By making greatest use of protective devices. This refers to rebuilding of old arresters and applying new arresters close to their maximum capability, thereby reducing the content of critical materials in the arresters themselves.

2. By proper use and maintenance of protective devices, failures from lightning of important machines and equipment which would require large amounts of critical materials and man-hours to replace can be minimized, thereby maintaining a high degree of service to important war loads.

It is not to be implied that the suggestions contained in this report are the only means worth-while in attempting to save critical materials, nor that they are recommended as expedient in all cases. It should be clearly understood that local conditions, service requirements, and many other such factors may have to be considered before reaching a decision as to whether or not it is advisable to use one or more of the proposed schemes.

The importance of a check up and study on existing systems of overvoltage protection against lightning to obtain better protection cannot be overemphasized. This type of study applies to both new and existing installations.

II. Suggestions for Saving Critical Material

The suggestions presented and discussed hereinafter are backed in most cases by successful operating experience. The experience record, however, does not pretend to be all inclusive as it has not been expedient to survey thoroughly the entire field throughout the country to obtain and analyze detailed records. Where diverse views of committee members have existed, this situation is pointed out.

1. Applying arresters on basis of voltage rating.
2. Rebuilding and revamping old arresters.
3. Short connections between arresters and equipment.
4. Line-type arresters in place of station-type.
5. Protection of equipment not already protected.
6. Protective devices other than arresters.
7. Shielding of stations.
8. Tests and maintenance of arresters.

The eight suggestions are discussed in order.

1. Applying Arresters on Basis of Voltage Rating

It is generally recognized that a lightning arrester has a maximum normal frequency (60-cycle) voltage rating just as any other piece of equipment like a transformer, breaker, or disconnecting switch. Although tolerances of over-voltage for these latter types of equipment are specified in standards, they are undoubtedly often exceeded in service. The arrester differs from other types of apparatus in one respect, namely, that its maximum voltage rating should not be exceeded under any operating condition; otherwise, the arrester may be severely damaged. The use of an arrester on a system where the line-to-ground voltage exceeds the arrester rating, even for a few cycles, may well be viewed with concern. If arrester failure occurs because of abnormal system overvoltage, it is very likely that the arrester has been misapplied.

In general, arresters listed in the manufacturers' catalogs for nongrounded neutral systems have a maximum rating of approximately five per cent above line-to-line system voltage and those applied to effectively grounded neutral systems have a factor of safety of approximately 40 per cent above system leg voltage (80 per cent of the line-to-line voltage).

In cases where the ungrounded neutral arrester has been used on a grounded neutral system, a saving may be effected by using the grounded neutral arrester, provided the system neutral is grounded effectively. Also, there are certain cases where an accurate calculation of the system overvoltage on grounded neutral systems has resulted in application of arresters having a lower rating than the general manufacturer's guide for the selection of arresters indicates.

For example, on one particular system rated 132-kv grounded neutral, an arrester having a maximum line-to-ground rating of 109 kv has been used successfully. In this particular case the use of a lower arrester rating has resulted in the use of power equipment with lower insulation (115-kv class insulation instead of 138-kv class which would normally have been required). In this connection, it should be realized that the lower the rating of arrester used, the greater the degree of lightning protection to the equipment, but on the other hand, there is less factor of safety in the arrester.

2. Rebuilding and Revamping Old Arresters

Another factor to be considered is the savings of materials possible by rebuilding or revamping old type arresters. Several companies have reported that they have been doing work along these lines for some time. In the case of oxide-film arresters which were extensively used in the past, it is general practice in a number of companies to reduce the number of

Paper 43-111, recommended by the AIEE committee on protective devices for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21-25, 1943. Manuscript submitted May 5, 1943; made available for printing May 27, 1943.

Personnel of lightning arrester subcommittee: I. W. Gross, *chairman*; Edward Beck, F. M. Defandorf, R. H. Earle, H. N. Ekvall, Herman Halperin, J. R. McFarlin, E. E. Piepho, W. J. Rudge, A. H. Schirmer, H. R. Stewart, J. M. Towner, E. R. Whitehead, E. H. Yonkers.

This report was prepared by the AIEE lightning arrester subcommittee of the committee on protective devices for the purpose of making essential information immediately available to war industries, thus furthering the conservation of valuable material for the war emergency. It is educational and in no way mandatory. It is not intended as a "Standard," and has not been formally approved by the standards committee or the board of directors.

cells in existing arresters which, in effect, means reducing the arrester rating to match more nearly anticipated normal frequency overvoltage conditions of the circuit where they are used. The principle involved has been discussed. Likewise, the changing of four-leg oxide-film arresters to the three-leg type has been an accepted practice for some time with outstanding success from the viewpoint of added protection and absence of arrester failure. Of course, in such cases the 60-cycle maximum rating of the remaining three legs must be checked against the system overvoltage under fault conditions. In some cases where the three-leg 60-cycle rating was too low, part of the fourth leg was left in service to supply the deficiency.

Successful rebuilding of mica-spaced and open-gap auto-valve arresters has also been reported. The rebuilding of old arresters supplies added protection to equipment where they are installed by lowering the protected level and also may make available some of the material removed for other arrester locations or spare parts. The rebuilding of even obsolete arresters may in some cases be warranted, if new arresters are not available. The added protection of rebuilding obsolete arresters may in some cases be justified, although the protected level may be higher than would ordinarily be desired.

3. Short Connections Between Arresters and Equipment

The desirability of having short connections between the arrester and the equipment it is to protect has been discussed extensively in technical literature in the recent past. It probably does not require further amplification here. It is well known by theory and test that while the arrester may hold a given voltage at its own terminals, this voltage may be quite different at the terminals of protected equipment if long leads intervene to the lightning arrester. Even in distances of 25 to 50 feet, on steep front surges, it is generally recognized that the voltage at the equipment may be increased appreciably by virtue of the lead length.

The importance of considering this factor is evident for two reasons: first, less protection is supplied to equipment already in service where lead length is considerable. This is, of course, equally true of new installations of protective equipment. Second, there may be some saved or salvaged copper by proper consideration of this lead-length feature.

Another saving which can be effected in copper conductor is that of using substantial structural work in stations such as columns, trusses, and so forth, for part of the lightning discharge path to ground. In many cases in the past, common practice has been to extend separate grounding leads from the ground end of the arrester to ground, even though the main structural part of the station was electrically tied into the grounding system. This extra refinement, it is felt, under wartime emergency conditions, is not necessary and probably results in very little, if any, increased protection by adding the ground lead from the arrester to the equipment where a suitable and substantial steel structure or network already exists.

4. Line-Type Arresters in Place of Station-Type

In the installation of new equipment, it often is possible to maintain sufficient margin between the distribution-type-arrester characteristic and the insulation strength of present-day equipment. Where old equipment only is involved, it is doubtful whether the substitution is worth while, and in fact, it may often be found that the protective level supplied by even modern station arresters is unduly high so that the use of line-type arresters cannot even be considered.

Several successful applications of line-type arresters on new equipment have been made with satisfactory operating experience. It should be pointed out, however, that many of the applications coming under this classification result more often in economies than in a material reduction in the use of critical material or in saving of manpower.

5. Protection of Equipment Not Already Protected

Secondary savings considerably greater than cost of applying lightning arrester protection are usually possible in cases where equipment is not now protected. It is not the intention of the committee to recommend that all equipment not now protected should be immediately supplied with arrester protection, but there are undoubtedly existing installations and new ones being made where the expenditure of a small amount of critical material in lightning arresters may produce large secondary savings by preventing failures of important equipment. This feature is pointed out as one worth considering and studying in individual applications. The decision reached will be influenced by many factors such as exposure of equipment to lightning, its importance in service, the possibility of replacement, cost and time of replacement, and similar factors.

6. Protective Devices Other Than Arresters

While the lightning arrester has been mentioned frequently in this report, the general features of application of overvoltage protective devices considered here apply in most cases to other protective equipment such as rod gaps, shielded gaps, De-ion gaps, and similar devices. Where to use one in preference to another is entirely outside the scope of this report to recommend. However, it is suggested that careful consideration be given in the application of any protective devices to insure that a suitable margin between the voltage level held and the strength of the equipment be maintained. It should be pointed out, however, that all of these devices mentioned have been reported by some users as giving successful and satisfactory service within their scope of application.

7. Shielding of Stations

Where a large amount of equipment is placed in one location such as at major stations, the general practice in recent years has been to supply adequate shielding from lightning by the use of elevated ground wires or ground networks, and even in some cases, by individual lightning rods shielding equipment. While such protection requires the use of some critical material, it may well be considered from the point of view of spending a relatively small amount of critical material for shielding to prevent damage to equipment having a much larger amount, the replacement of which would probably necessitate an expenditure of critical material and manpower.

8. Tests and Maintenance of Arresters

In so far as the arrester itself is concerned, it is suggested that special consideration be given to testing arresters wherever possible and feasible, to insure that they are in the best of condition to perform their expected functions. Several years ago recommendations were made by the AIEE lighning arrester subcommittee on methods of testing some types of arresters. Since that time, a large number of arresters have been tested, and other methods of test or refinements have been

Interim Report on Emergency Overloads on Overhead Conductors

AIEE WORKING GROUP ON TOWERS, POLES, AND CONDUCTORS

Preface: The present war emergency requires that the maximum use be made of existing equipment and systems and that a minimum of critical material be used for new equipment.

This publication, and other guides and reports in this series, have been prepared for the information of users during the war emergency. Upon termination of the war emergency they will be reconsidered by the standards committee and the committees which prepared them, and will be approved, revised for normal use, or rescinded.

This procedure is being followed in preference to the preparation of special emergency standards which might involve redesigning and drastic changes in manufacturing practices. These guides will accomplish the maximum conservation of critical materials, since they provide for the maximum use of existing equipment and systems, as well as new equipment without changing the fundamental basis on which the present standards have been prepared.

PRESENT restrictions in the use of materials and sharp increases in loads may make it necessary to load existing lines to the thermal capacity of the conductors. The purpose of this report is to call attention to the limiting factors and the information available from which to evaluate the limits.

The problem divides itself into two parts, the temperature at which the conductor may be operated without impairing its strength or destroying its covering, and the temperature the conductor will attain for a given current density under any given conditions. Neither of these can be calculated with any degree of precision, and the probable error must be duly considered in establishing emergency ratings for any conductors.

Paper 43-105, recommended by the AIEE committee on power transmission and distribution for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21-25, 1943. Manuscript submitted May 5, 1943; made available for printing May 25, 1943.

Personnel of the working group on towers, poles, and conductors: Edwin Hansson, *chairman*; C. A. Booker, H. A. Clark, A. E. Davison, F. W. Packer, G. W. Stickley, E. O. Wahlstrom.

This interim report was prepared by the AIEE working group on towers, poles, and conductors of the transmission subcommittee of the committee on power transmission and distribution for the purpose of making essential information immediately available to war industries, thus furthering the conservation of valuable material for the war emergency. It is educational and in no way mandatory. It is not intended as a "Standard," and has not been formally approved by the standards committee nor the board of directors.

I. Permissible Temperatures

A. Loss of Strength Caused By Annealing

The annealing point of the softer metals hardened by cold working, is not very definite. Variations are introduced by impurities and by the amount and rate of cold working. Time is also an important factor, and it is not definitely known if effects of intermittent heating are directly additive or not.

Aluminum. G. W. Stickley gives the following figures for annealing of hard drawn aluminum. "In tests of wire heated one hour at 100 degrees centigrade the strength was decreased only two per cent, and after heating at this temperature for as long as four years the decrease was only 15 per cent. In similar tests of wire heated one hour at 150 degrees centigrade the strength was decreased only about five per cent. It should be noted that although overloads might have a small effect in decreasing the strength of aluminum conductors, they would have still less effect upon the strength of steel reinforced aluminum cable. Tests of the high-strength steel wire used as the core of ACSR have shown that heating at temperatures as high as 260 degrees centigrade for two months actually increases the strength of the wire slightly."

Howell and Paul[1] state that commercially pure aluminum in the hard drawn temper, designated 2*S-H*, is not materially softened by prolonged exposure to temperatures in the region of 200 degrees Fahrenheit.

Copper. Many data on annealing of copper have been published, but the values given vary over an extreme range. If the conductor is kept at 171 degrees centigrade, Anaconda claims ten per cent softening in one hour, while General Cable Company finds that it requires 6.7 hours to produce ten per cent softening at 175 degrees centigrade. H. R. Stewart states results from actual tests as follows: A number two copper wire held at 215 degrees centigrade and a number 1/0 held at 160 degrees centigrade for four hours each lost about five per cent of its strength. Kidder and Woodward[2] find that copper may be held at 180 degrees centigrade for eight hours on six consecutive days (total 44 hours) with 16 per cent loss in strength, and when heated to 200 degrees centigrade for the same length of time it lost 35 per cent. From this they conclude that the danger zone lies about 175 degrees centigrade for short duration.

A very complete investigation is presented by Myron Zucker.[4] It shows that the annealing temperature is affected by the amount of cold working and the purity of the copper. The harder the copper, the lower the annealing temperature. A small percentage of silver will raise the annealing temperature considerably, while oxygen will lower it. He summarized his findings in curve form, giving a spread of from 40 to 1,200 hours at 100 degrees centigrade for copper in the electrolytic range. He also states that an X-ray diffraction test can be used to determine the annealing characteristics of copper without destroying the sample. The beginning of recrystallization indicates a loss of five per cent of the tensile strength of the wire.

In most cases, annealing tests on copper

used. It cannot be too strongly urged that a special attempt should be made to keep the arresters and their grounding connections in the best possible condition.

Summary

The features in the preceding paragraphs have been presented and discussed with the thought in mind that the information may be helpful to those who have the lightning or overvoltage protection problem to deal with. It is not intended that all of these suggestions be applied without careful study and thought; in fact, unless such a detailed study is made of systems now in use or proposed, the full benefits of the applications suggested will most likely not be obtained. It is hoped that this paper will stimulate constructive thought on the part of those who have the responsibility of designing and operating protective systems already installed or to be installed in the future.

It should be kept in mind that in applying some of these *suggestions*, the failure rate on the protective devices themselves may increase, but it is believed that if the conditions of each situation are considered and action taken on an engineering basis, the net over-all effect will be of considerable benefit to the war effort.

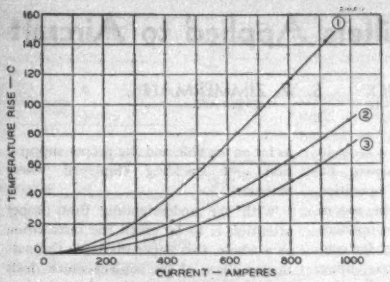


Figure 1. Temperature rise of 795,000-circular mil steel-reinforced aluminum cable, new

Tests made at 60 cycles indoors in still air on unused cable from stock. Cable not weathered but no longer bright

1. Cable in Ohio Brass number 77,898 suspension clamp (without armor rods)
2. Cable with armor rods in Ohio Brass number 77,613 suspension clamp
3. Bare conductor, with neither armor rods nor suspension clamp

have been designed to determine the length of time required for complete annealing at different temperatures. The difficulty in exterpolating these data to a time–temperature combination which would give a small percentage of annealing may be responsible for the wide discrepancy in values.

Before the question of annealing can be definitely answered, information on the effect of the following items must be known:

Various impurities commonly found in commercial metals.

The cold working required to make the metal into wires or cables.

The stresses to which the conductor normally is subjected.

Intermittent heating and possible recovery between heating periods.

Copperweld. The strength of a copperweld conductor is predominated by the steel content, and it is not likely to be loaded to a point where its mechanical strength is impaired. Rolf Selquist suggested that the current-carrying capacity of copperweld be limited to 70 per cent of that of a copper conductor of the same cross section.

B. Protection of Wire Coverings

Kidder and Woodward[3] state that with a copper temperature of 175 degrees centigrade the outside surface of the covering will be 130 degrees centigrade, which is well below the impregnating temperature, and 80 degrees centigrade, or just below the standard acceptance specification with a copper temperature of 100 degrees centigrade. Myron Zucker[4] stated that recent tests on *URC* covering indicate that it can be safely operated for ten hours at 100 degrees centigrade. The compound used in older types of weatherproofing gets soft and tacky at temperatures as low as 60 degrees centigrade and the *URC* covering begins to soften at 85 degrees centigrade. It is reasonable to assume that such temperatures are going to accelerate the deterioration of the covering. In many cases it may well be that this would be of little importance as compared to the additional capacity gained.

C. Preservation of Clearances

Operating conductors at elevated temperatures will mean considerable increases in sag. Where maintenance of clearance

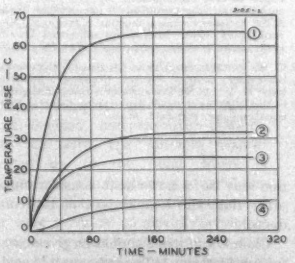


Figure 2. Rate of temperature rise of 795,000-circular mil steel-reinforced aluminum cable, new

Tests made at 60 cycles at 550 amperes, indoors in still air on unused cable from stock. Cable not weathered but no longer bright

1. Cable in Ohio Brass number 77,898 suspension clamp (without armor rods)
2. Cable with armor rods, in Ohio Brass number 77,613 suspension clamp
3. Bare conductor, with neither armor rods nor suspension clamp
4. Cable with armor rods, but without suspension clamp

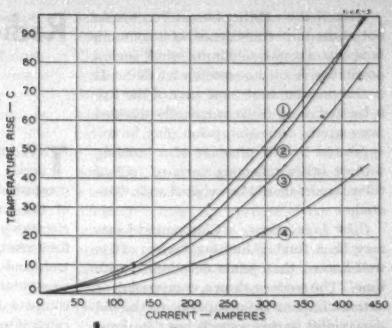


Figure 3. Temperature rise of badly oxidized seven-strand 2/0 copper cable

Tests made at 60 cycles indoors in still air. Conductor badly oxidized from many years of service

1. Cable in Ohio Brass number 70,757 suspension clamp and number 70,759 keeper (horns removed)
2. Thermocouple between core strand and outside layer
3. Thermocouple on surface of cable
4. Memco number 64 twisted sleeve

is important, these increases should be carefully checked. Even small amounts of annealing may result in permanent stretch of the conductors after a heavy ice load, and it may become necessary to resag the line.

II. Temperatures That the Conductor May Attain

A. Temperature Rise Versus Current

Several references covering the heating of conductors from electric currents are available in the engineering literature.[2,5–9] The formulas given by Schurig and Frick seem to give consistent results. Kidder and Woodward[3] give a detailed description of their method of its application.

B. Weather Conditions

The temperature rise of the conductor must be co-ordinated with the ambient temperature, wind conditions, rainfall, and so forth. The frequency and duration of high temperatures in combination with low wind velocities may be found from local weather records. These data may be plotted in various combinations to give a picture of the probability of high temperature with little or no wind coinciding with maximum load. One reason for overloading a circuit may be the tripping of a parallel circuit during a lightning storm, making it desirable to make a study of weather conditions immediately following lightning storms.

Even if the weather bureau records do not show any coincidence of maximum temperature with minimum wind, such a possibility is by no means excluded. It is also possible that some part of the line is located so as to be practically shielded from wind. Sun absorption may be exaggerated by the presence of a building wall or other reflecting surface. All of these factors should be weighed and evaluated.

Other Limitations. Clamps and joints may be a further limiting factor. It is well known that joints deteriorate with time. The modern, drawn, compressed, or automatic joint is far superior to the old sleeve joint in this respect, but deterioration in some degree is bound to take place.

Most suspension and dead end clamps in use today form a more or less closed magnetic circuit around the conductor, and losses at 60 cycles are appreciable. This was brought out by W. H. Burleson. A test on a 500,000-circular mil copper conductor gave a temperature rise of the clamp 80 per cent higher than that of the conductor proper at a current of 800 amperes. The results on another test on a 795,000-circular mil ACSR, with 550 amperes, shown in Figure 1, indicate a considerable cooling effect of the armor rods, and that the temperature of the clamp (without armor rods) reached two and one-half times that of the conductor. Figure 2 shows that while the rise is rapid during the first hour, it requires almost four hours to reach a stable condition. In a weathered conductor, Figure 3, the center or core strand may reach a temperature 15 degrees centigrade in excess of that of the surface strand. This steep gradient, on the order of 5 degrees centigrade to 7 degrees centigrade, has also been found by Zeerleder and Bourgeois.[2]

Conclusions

If permanency and safety of the line are to be considered, emergency ratings must be extremely conservative when based on our present knowledge. A sample test of the conductor in question cannot be considered a reliable answer as to the annealing characteristics of the conductors along the entire line. The lot may have been purchased from a single manufacturer, on a single order, and yet may have been made from two or more different lots of metal.

This does not necessarily mean that it would be unsafe to increase the rating of a line over previous standards. In many cases a substantial increase is possible, even if the various factors are chosen on a conservative basis, and the final limitation may be found to lie in considerations other than the temperature of the conductor.

Clamps and joints should be given careful consideration. The maximum annealing effect is apt to be found where the stresses in the conductors are at a maximum.

Surface measurement of conductor temperatures may be misleading by ten per cent, or more.

References

1. The Properties of Aluminum and Two of Its Alloys at Elevated Temperatures, Howell, Paul. *Metals and Alloys*, volume 5, August 1934, page 177.

2. Effect of Temperature Attained in Overhead Electric Transmission Cables, A. V. Zeerleder, P. Bourgeois. *Journal* of the Institute of Metals, volume 42, 1929, page 321.

3. Ampere Load Limits for Copper in Overhead Lines, A. H. Kidder, C. B. Woodward. AIEE Transactions, volume 62, 1943, March section, pages 148–52.

4. Thermal Rating of Overhead Line Wire, Myron Zucker. AIEE Transactions, volume 62, 1943, July section, pages 501–7.

5. Heating and Current-Carrying Capacity of Bare Conductors for Outdoor Service, C. R. Schurig, C. W. Frick. *General Electric Review*, 33, 1930, page 141.

6. Current Capacity of Wires and Cables, George E. Luke. *Electric Journal*, 20, 1923, page 127.

7. Effect of Wind on Temperature Rise of Transmission Line Conductors, H. Gandefroy, K. H. Lippitt. *General Electric Review*, 38, 1935, page 373.

8. Conductor Load Limits Readily Determined, E. P. Peek, H. B. Vincent, Jr. *Electrical World*, 103, 1934, page 912.

9. Heating of Large Steel-Cored Aluminum Conductors, R. J. C. Wood. AIEE Transactions, volume 43, 1934, October section, pages 1258–62.

Radio-Noise Filters Applied to Aircraft

C. W. FRICK
ASSOCIATE AIEE

S. W. ZIMMERMAN
MEMBER AIEE

THE importance of the use of radio in aerial navigation is well known. Of comparable importance to the operation of the aircraft, however, is the use of electricity in other forms, as for instance for engine ignition, for lighting, for control, and a variety of purposes. Since commutators and other forms of arcing contacts used in this equipment may cause interference with radio under some conditions, careful planning is necessary to get the fullest use from both power and radio equipment, and not overburden the aircraft with attachments solely to make the radio work.

In order to obtain installations which are reasonably free from radio interference of this kind, due consideration must be given to all of the component parts. For example, attention should be given to the shielding of radio equipment so that it will not be subject to direct pickup of radio noise phenomena. Furthermore, unnecessarily close proximity of power and radio circuits to each other, which gives close coupling for radio noise, should be avoided. In regard to the power equipment, disturbances which give rise to interference should be avoided as far as possible and the proper suppression and shielding employed where necessary.

With the understanding that proper attention is to be given the installation as a whole, this paper discusses the particular phase of the subject which deals with control of radio interference as a complex voltage on the power circuit called radio-influence voltage. Reducing or suppressing this voltage reduces the noise in the radio set resulting from this cause. The paper deals particularly with two suppression devices, capacitors, and radio-noise filters. Filters have been especially useful in many situations on aircraft equipment. They provide an effective and practical means of suppression for these applications.

Paper 43-132, recommended by the AIEE committee on air transportation for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21–25, 1943. Manuscript submitted May 5, 1943; made available for printing May 25, 1943.

C. W. Frick is engineer in the general engineering laboratory, General Electric Company, Schenectady, N. Y. S. W. Zimmerman is research engineer in the lightning arrester department, General Electric Company, Pittsfield, Mass.

Available Filters

Manufacturers of filters have made available certain sizes of filters intended to cover a large majority of the requirements for aircraft. Filters are available in 25-, 50-, 100-, and 200-ampere ratings applicable to d-c circuits up to 50 volts. These filters are contained in a metal case which is provided with suitable mounting brackets.

These filters consist of a series line inductance with a capacitance at each end. Two terminals are arranged for connection of the filters in series with one side of the power circuit in which the noise volt-

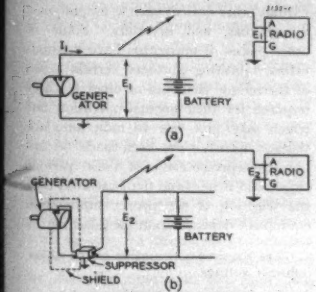


Figure 1. Elementary case of power circuit and radio receiving system

(a.) Without suppressor
(b.) With suppressor

ages are to be suppressed. The other side of the power circuit is grounded, and the filter case is also grounded. When tested in a circuit with aircraft equipment, noise-reduction ratios in the order of 200 to 1 to 5,000 to 1 (46 to 74 decibels) are obtained over the frequency range of 0.20 to 20 megacycles. Also on a circuit standardized for rating performance, noise reductions of 1,000 to 1 to 10,000 to 1 (60 to 80 decibels) are obtained over the same frequency range. Weights of these filters range between 1.5 and 3.0 pounds depending on current rating. Over all outside dimensions including mounting flanges range in length, breadth, and height from 4 by $3^3/_4$ by $2^1/_2$ to $5^1/_2$ by $4^1/_4$ by 3 inches, respectively. The filters will retain their suppression characteristics over a temperature range of 40 degrees centigrade below zero to 90 degrees centigrade above zero. Vibration tests in all possible positions of filter operation and at frequencies and amplitudes met with in service insure against mechanical failures.

Factors Entering into the Problem of Interference Control

The following discussion is intended to bring out by means of a simple example a number of points which should be understood in order to select, install, and test properly suppression devices, and some of the terms commonly used.

An elementary case of a power circuit and a radio receiving system is shown in the upper diagram *a* of Figure 1. The supply generator has a commutator which produces small but extremely rapid changes in the current and voltage. This causes a disturbance voltage and current, indicated at E_1 and I_1. In this diagram only the disturbance component is represented, the power voltage and current being omitted for clearness. The disturbance voltage and current result from a complex phenomenon involving very rapid changes and can, therefore, be treated as radio-frequency voltage and current, not of a single frequency but a spectrum covering a wide range of frequencies. The presence of this voltage and current E_1 and I_1 in the power circuit causes induction in the paralleling radio circuit, similar to the induction which takes place when a radio-frequency voltage is applied to the power circuit. The induced disturbance voltage which appears at the antenna and ground terminals of the radio set is indicated by e_1 and is called radio-noise voltage. The disturbance voltage on the power circuit which produces radio-noise voltage on an antenna, already described and indicated at E_1, is the radio-influence voltage (*RIV*). Both of these quantities can be measured in microvolts at various frequencies by means of a frequency-selective instrument called the radio-noise meter.[1]

There are several ways in which the possibility of interference with radio because of power equipment can be minimized, some of which are as follows. Referring to the elementary case of Figure 1*a*, it is evident that physical separation between the power circuit and the radio circuit would reduce the radio-noise voltage. However, space limitations in an aircraft make it impractical to control interference by this means alone. It is also evident that complete shielding of the radio system would eliminate or reduce the radio-noise voltage. An example of complete shielding would be a well-shielded, independently powered radio set with the antenna lead-in shielded up to the point where it emerges from the fuselage of a metal aircraft. A similar result would be obtained if it were practical to shield completely the power system by enclosing the generator, battery, and other apparatus in metallic containers and running connecting wires in continuous metal conduit. The shielding of power circuits carrying 100 amperes or more and extending to all parts of the aircraft has the disadvantage of weight and inconvenience in servicing the power system. However, complete shielding is commonly applied to some types of apparatus and circuits as, for instance, engine ignition.

Referring again to Figure 1*a*, it is seen that reducing or suppressing the radio-influence voltage E_1 reduces the radio-noise voltage e_1. This can be accomplished either by reducing the disturbance itself or by localizing, that is, confining the disturbance in the apparatus which produces it. A radio-noise suppressor is a device which does this. It is connected to a piece of apparatus such as a generator as indicated in the lower diagram *b* of Figure 1. It does not obstruct the flow of normal power but does prevent the flow of the unwanted disturbance. In terms of radio-influence voltage the purpose of the suppressor is to reduce the voltage E_1 of Figure 1*a* to a smaller value E_2 shown in Figure 1*b*. This results in reducing the radio-noise voltage e_1 to a smaller value e_2. The ratio E_1/E_2 called attenuation ratio is a measure of the effectiveness of the suppressor. It is often expressed in decibels (db) according to the relation

$$\text{db} = 20 \log_{10} \frac{E_1}{E_2}$$

This is called attenuation or insertion loss. The performance of a representative suppression device, in this case a filter, in a circuit such as Figures 1*a* and 1*b*, is shown by Figure 2 wherein the upper curve (E_1) shows the *RIV* without the filter and the lower curve (E_2) shows the *RIV* with the filter, plotted against frequency. The ratio of these two quantities, also plotted against frequency, is shown on Figure 3. Two vertical scales are given, one showing numerical ratio, and the other insertion loss in decibels.

Suppressor Arrangements

Suppressors have been applied to power circuits in many cases for such purposes as smoothing out ripples present in a d-c voltage or reducing distortion of an a-c voltage as well as reducing radio noise.

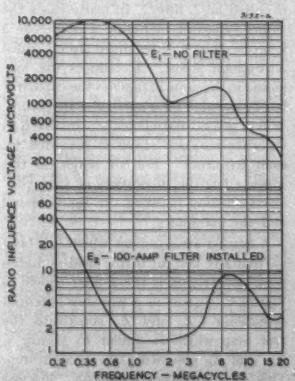


Figure 2. Radio-influence characteristics of airplane generator circuit

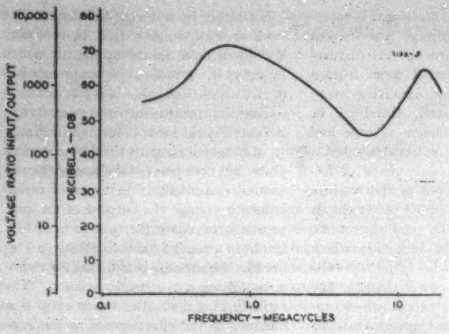


Figure 3. Attenuation characteristics of 100-ampere filter from generator test data

While many different suppressor arrangements might be used, experience indicates that certain simple structures can be used to best advantage. Figure 4 shows a simple arrangement for smoothing out the ripple present in the voltage of a certain d-c machine. It consists of a shunt capacitor across the terminals. The capacitor does not pass direct current and hence does not interfere with the normal operation of the machine. In the diagram E_e represents the ripple voltage, Z_e represents the impedance of the machine for this ripple, and Z_c represents the corresponding impedance of the capacitor. It will be seen that Z_e and Z_c act as a potential divider for the ripple voltage E_e. For example, if Z_c is one tenth of Z_e, only one tenth of E_e appears on the outgoing circuit. In other words, this arrangement gives 10 to 1 reduction (20 decibels).

Sometimes it is advantageous to add impedance to the machine as at Z in Figure 5, especially if the machine itself has very little impedance. This arrangement is called an L filter. In many cases the shunt capacitor of Figure 4 or Figure 5 is replaced by a series tuned circuit called a resonant shunt. It reduces the harmonic in the same manner as the capacitor but is selective for a particular frequency. When several harmonics are involved, a separate resonant shunt is provided for each frequency. For a-c machines this scheme has the advantage of frequency discrimination between the fundamental and the harmonics.

A further arrangement which has been particularly helpful in the field of radio-noise suppression is the π filter shown in Figure 6. It acts as a two-step potential suppressor. Z_a and Z_{c1} constitute the first step which is similar to Figure 4. Z_{L2} and Z_{c2} constitute the second step. This affords further reduction. For example, if each step gives 10 to 1 reduction or 20 decibels, the over-all reduction will be 100 to 1 or 40 decibels. A practical aircraft filter of this type is shown in Figure 7.

The L filter and the π filter are similar in structure to certain simple filters known as low-pass filters employed in communication practice.

Use of Suppressors in Aircraft

The selection of a radio-noise suppressor to fit a given situation and the proper way to install it so that it will function properly involves a number of considerations which are discussed in the sections which follow. These considerations are brought out with reference to a type of aircraft power-supply system that has been studied extensively, but the conclusions are not necessarily restricted to this type of system. A common situation is that of a power supply consisting of one or more generators driven from aircraft engines and operated at about 28 volts d-c, a two-wire circuit, one side of which (usually the negative side) is solidly grounded to the body of the aircraft, stand-by storage batteries, motors, and

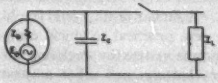


Figure 4. Capacitor as suppressor

Figure 5. L filter as suppressor

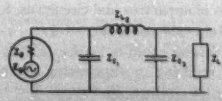


Figure 6. π filter as suppressor

various other devices such as amplidynes, dynamotors, and inverters. Some of these pieces of apparatus have commutators, vibrating contacts, certain types of thermionic elements or other features required for their normal operation but which may give rise to radio-influence voltage. Tests have been made on apparatus representative of these various types, and it has been demonstrated that the selection of the proper suppression equipment depends upon the following:

1. The required attenuation of the radio-influence voltage.
2. The frequency range to be covered.
3. The impedance characteristics of the apparatus and circuit.
4. The power currents which the suppressor device must be able to carry.

Complete quantitative data on the first three items are not usually at hand, and most situations have to be treated on the basis of representative tests and experience with the use of suppression devices. With the aid of such knowledge, the kind of suppression equipment to employ can be decided upon. In some cases a capacitor as in Figure 4 can be used to best advantage. In other cases a filter arrangement such as Figure 5 or Figure 6 gives the best results. The general field of application for capacitors and for filters will now be considered.

Capacitors as Suppressors

There are many cases of devices having small current ratings such as five amperes or less on which capacitors may be used effectively, for example when the required attenuation ratio is between 10 to 1 and 100 to 1, and the frequency range is not large, such as the range of standard broadcast frequencies. A capacitor has the property of very low impedance at high frequency. In the case of an ideal capacitor the higher the frequency, the lower the impedance becomes. It must be remembered, however, that every resistor, inductor, and capacitor possesses to some degree all three of the properties—resistance, inductance, and capacitance. In the case of the capacitor some means of connection to the apparatus circuit is necessary, and these connections may have appreciable length and, therefore, appreciable inductance. To determine the effect of these properties a capacitor was tested in a circuit similar to Figure 4 with resistances used to represent the circuit impedances Z_e and Z_L. Voltage was measured with capacitor off and capacitor on. The ratio of voltage E_1 with suppressor off as in Figure 1*a* to E_2 with suppressors on as in Figure 1*b*,

which is the attenuation ratio is shown in Figure 8 plotted against frequency.

The straight line, dotted at the upper end, represents the calculated attenuation for a pure capacitance. The solid curve shows the actual attenuation. It will be noted that the attenuation over the lower part of the frequency range coincides with the pure capacitor, but the attenuation at the upper end is quite different and is characterized by a peak at point *A*. At this point actual performance exceeds the calculated performance based on pure capacitance mainly caused by capacitor resonance, but there is a rapid falling off of attenuation ratio at frequencies above this peak, instead of an increasing attenuation ratio as there would be with an ideal capacitor. The frequency at which the peak occurs in the case of the capacitor tested, which was of a special design for high frequency, was between five and ten megacycles. The characteristic of another capacitor of the same microfarad value but not specially designed for high frequency is shown by the broken line for comparison. The shape of the latter curve indicates that the capacitor has somewhat more inductance and more resistance at high frequencies, which limit its effective range to about two megacycles.

Referring to the "high-frequency" capacitor, the maximum effectiveness, and the frequency at which it occurs, at *A*, depend upon all three of the quantities—resistance, capacitance, and inductance. In this frequency region increasing the capacitance does not necessarily increase the effectiveness and may result in reduced effectiveness depending on the other factors. Sometimes advantage is taken of the "peak" effectiveness by choosing suitable values of capacitance and length of leads to control the inductance so that the peak occurs at a desired frequency. The usefulness of this scheme is somewhat limited, and it is generally preferable to make the capacitor leads as short as possible.

The curve of Figure 8 indicates in a general way the field of application for capacitors as suppressors. At the lower end of the curve which in this example corresponds to about 0.2 megacycle, the capacitor has less effectiveness than at the higher frequencies. While the effectiveness at this frequency can be improved by making the capacitance value (microfarads) larger, this usually results in considerable size and weight. A further increase in attenuation can be obtained by means of a filter such as Figures 6 and 7 with less bulk and weight. At the upper end of the frequency range, that is, above

Figure 7. Radio-noise filter showing compact arrangement required

five or ten megacycles, the effectiveness of the capacitor is limited by the inductance of leads and other factors besides capacitance. In and above this frequency range it is usually necessary to use a filter giving an attenuation curve such as Figure 3. In the frequency range from about one to five megacycles there are many cases where the capacitor as a suppressor is the best solution. The most important considerations in the use of capacitors as suppressors are the characteristics of these capacitors in the desired radio-frequency band and the proper arrangement of leads and connections.

Whether capacitors are used instead of filters depends on

(*a*). The economies.

(*b*). The allowable weight and size.

(*c*). The required performance.

Filters As Suppressors

When apparatus rated one kw or more has to be suppressed over a wide range of frequencies such as 0.2 to 20 megacycles and suppression of 40 decibels or more is required, a capacitor is not generally sufficient for reasons already shown, and some form of filter is necessary. While in some instances filters have been specially designed and assembled as part of a piece of equipment, the general situation calls for the availability of filters as separate items to be selected and applied as the need arises. Manufacturers have made available certain sizes of filters intended to cover a large majority of these requirements. To meet as

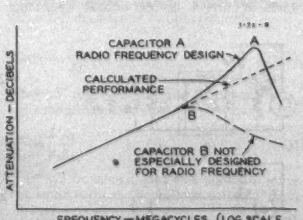


Figure 8. Radio-influence voltage suppression characteristics of capacitors

nearly as possible the general requirements outlined, these filters are designed to give attenuation characteristics based on measurements on a variety of apparatus and experience of aircraft operators over the frequency range of radio equipment used in aircraft. Impedance characteristics of aircraft equipment and circuits have been taken into account in a general way by the use of a laboratory test setup to be described later.

To illustrate the application of these filters the case of a 2.5-kw 28-volt d-c generator will be considered. The full-load current of this machine is 90 amperes approximately. The filter rated 100 amperes would, therefore, be selected and installed as illustrated in Figure 1*b*. Filter performance is illustrated by Figure 2 already referred to in this paper, when the filter is properly installed.

In order to obtain the full degree of effectiveness which the filter is capable of giving, careful attention to certain installation details is necessary. While a generator is referred to as an example the discussion is intended to apply to a variety of apparatus. The filter should preferably be close to the generator. The intervening circuit must be shielded, the enclosure generally consisting of a conduit which forms a continuous shield with the generator and filter cases. The filter base must be well grounded, for instance mounted directly on the grounded metal structure. The grounded side of the circuit should be well grounded at a point immediately adjacent to the filter.

The importance of this and other factors to the proper functioning of such a filter can be seen by reference to Figure 9. Here three important factors are emphasized, all of which are usually present to a greater or less degree simultaneously. In these diagrams the filter is intended to isolate the radio-influence voltage appearing at the left from the circuit at the right but is not fully effective because of faulty coupling.

Capacitive coupling shown at *a* in Figure 9 is one of the conditions that may interfere with predicted good performance. It results from the presence of ex-

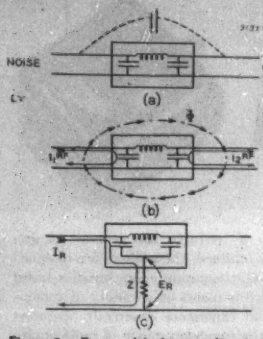


Figure 9. Types of faulty coupling in filters

traneous capacitance between input and output circuits as indicated by *C*. To high frequencies this provides a by-pass and allows extraneous voltages to appear in all or certain parts of the quiet circuit in spite of the presence of the filter.

Inductive coupling shown at *b* in Figure 9 is another condition to be avoided. If the impedance to radio-frequency currents flowing at the left is small, as it should be for a well-designed filter intended for suppression, radio-frequency currents flowing through this circuit may set up electromagnetic flux which if allowed to cut the conductors of a quiet circuit will introduce therein a radio-frequency disturbance as illustrated. In many cases magnetic shielding can be used to reduce this coupling. Electromagnetic flux at commercial frequencies must be shielded with heavy sections of magnetic material. At radio frequencies flux penetration can be prevented to a great extent with thin conducting surfaces. Inductive coupling occurs only when there are loops existing in input and output circuits.

Conductive coupling is a condition such as shown at *c* in Figure 9. Radio frequency currents in the circuit at the left flow through a common ground lead having an impedance *Z*. As a result voltage E_R appears across this impedance and is directly introduced in the circuit which is intended to be quiet. This type of induction may occur unless particular care is taken to secure a good ground connection. The case of the filter should be solidly connected to the electrical ground plane. The impedance of only a few inches of ground wire is extremely detrimental to filtering action.

To obtain a quiet circuit all sources of noise must be given attention. One filter can sometimes be arranged to suppress more than one source. For instance, if the generator in the aforementioned example has a voltage regulator which causes radio noise and all connections to this regulator are made between the generator and the filter, the filter suppresses noise from both sources. All other connecting wires such as field leads must also be connected on the generator side of the filter.

In general the important things to be given attention in the installation of a filter are location, shielding of the unfiltered parts of the circuit, and ground connections.

Figure 10. Insertion-loss tester for radio-noise filters

Measurements

Tests are needed to check the performance of filters under actual operating conditions and to obtain data on which further designs and improvements can be based. The effectiveness of filters is determined by making two measurements of radio-influence voltage preferably on an actual installation in an aircraft. These measurements are made

(*a*). Without filter in the circuit.

(*b*). With filter in the circuit.

Measurements on the input and output sides of the filter do not indicate the effectiveness of the filter because the filter itself changes the circuit constants. The necessary equipment for these tests consists of a radio-noise meter[1] and a reliable signal generator for calibration.

To get measurements within the accuracy[2] of the noise meter certain precau-

Figure 11. Insertion-loss tester for radio-noise filters

Rear view showing amplifier, oscillator, and power supply

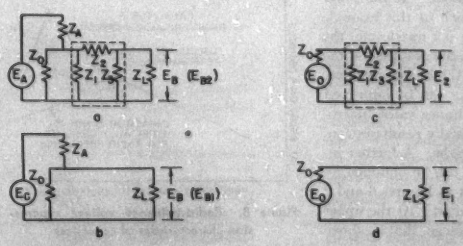


Figure 12. Laboratory circuit for rating filter performance and corresponding apparatus circuit

(*a*). Laboratory circuit, filter in

(*b*). Laboratory circuit, filter out

(*c*). Apparatus circuit, filter in

(*d*). Apparatus circuit, filter out

tions are necessary, particularly in tests made on an aircraft in flight. Among these are

(*a*). Maintenance of proper battery voltage.

(*b*). Proper alignment and adjustment of the noise meter and frequent calibration checks against the signal generator.

(*c*). Placing the noise meter close to the test point which in measurement with the filter should be right at the filter terminal on the "quiet" side.

(*d*). Avoiding test locations where the noise level is high.

(*e*). Providing the noise meter with cushions to eliminate mechanical vibration.

(*f*). Providing a temperature controlled chamber when low temperatures are encountered.

In addition to tests on the actual equipment it has been found useful to make tests on filters at radio frequencies in a laboratory circuit. This setup approximates in a general way the impedance characteristics of a piece of aircraft equipment and the asssociated circuit. The filter performance curves so obtained are not interpreted as those to be expected on apparatus but rather as those obtained in a standardized test circuit. However, the general experience has been that the filters showing the best performance on this network also showed the best performance in actual apparatus. This test has proved useful in the development of filter designs and in checking the product of the factory. Figures 10 and 11 show a filter tester based on this method used in a factory.

A diagram of the laboratory circuit in somewhat common use is shown in Figure 12 together with the corresponding apparatus circuit. Filter performance in this circuit is obtained by measurements without the filter in the circuit and with the filter in the circuit. The analysis given in the appendix shows that the laboratory circuit indicates the same performance as an actual apparatus circuit with a certain set of impedance values.

The measurements just described on a laboratory circuit or on the actual power circuit do not take into account the radio equipment and circuits. A complete study of filter performance should include measurements on the radio equipment, but consideration of the measurement equipment and technique for this purpose is beyond the scope of this paper.

Appendix. Laboratory Circuit for Filter-Performance Tests

The attenuation test commonly made on filters in the laboratory with sine wave voltages at radio frequencies utilizes a resistance network as shown in diagrams *a* and *b* of Figure 12. The voltage source or signal generator is represented by E_A. The circuit impedances Z_o and Z_L of a corresponding apparatus circuit shown by diagram *d* are represented by the same symbols on diagrams *a* and *b*. In the laboratory test these impedances consist of 20-ohm resistors. In addition a 300-ohm resistor Z_A is connected in series with the signal generator to adapt the circuit to the internal impedance characteristics of available signal generators. This 300-ohm resistor does not affect the test result because it cancels out in the "filter out" to "filter in" ratio as shown by the formulas in this appendix. In the diagram *a*, Z_1, Z_2, and Z_3 represent a π-filter (see Figure 6).

The test may be made in two ways. The first method is to hold the signal generator voltage constant and obtain two values of output voltage E_B, E_{B1} with filter out as shown in *b* of Figure 12 and E_{B2} with filter in as shown in *a*. The ratio $(E_{B1})/(E_{B2})$ is equal to the filter attenuation ratio, as will be demonstrated. The second method will be described later.

The following approximations which hold for practically all test setups have been made for the purpose of simplifying the analysis:

The paralleling effect of Z_L on Z_3 is neglected.

The paralleling effect of Z_o (to the left) and of other impedances (Z_3 and so forth to the right) on Z_1 is neglected.

The impedance looking into Z_2 from the left, diagrams *a* and *c*, is assumed to be the same as Z_2 itself, which neglects the added effect of Z_3 and Z_L.

The impedance looking into the circuit from the signal generator in *a* and *b* is assumed to be equal to Z_A which neglects the added effect of Z_1, Z_2, Z_3, and so forth. The largest error occurs in *b* where the actual value is 310 ohms and the approximate value is 300 ohms, the value of Z_A.

The impedance looking into the circuit from the source in diagram *c* is assumed to be equal to Z_2 which neglects the added effect of Z_1 and other elements to the right.

In diagram *a* the value of E_B is approximately

$$E_{B2} = E_A \frac{Z_1}{Z_A} \times \frac{Z_2}{Z_1} \tag{1}$$

When the filter is removed, as in *b*, and the signal generator voltage kept the same ($E_C = E_A$) E_B becomes approximately

$$E_{B1} = E_A \frac{Z'}{Z_A} \tag{2}$$

where Z' represents Z_o and Z_L in parallel.

Combining these equations we have

$$\frac{E_{B1}}{E_{B2}} = \frac{Z'Z_1}{Z_1Z_2} \tag{3}$$

It will be shown that this equation gives the same ratio as the voltage ratio E_1/E_2 in the apparatus circuit diagram *c* and *d*. In the former (filter in) the voltage E_2 is given approximately by the relation

$$E_2 = E_o \frac{Z_1Z_2}{Z_oZ_2} \tag{4}$$

In diagram *d* (filter out) the voltage E_1 is given by the relation

$$E_1 = E_o \frac{Z_L}{Z_o + Z_L} \tag{5}$$

Combining equations 4 and 5 we obtain

$$\frac{E_1}{E_2} = \frac{Z_oZ_L}{Z_o + Z_L} \times \frac{Z_2}{Z_1Z_2} \tag{6}$$

Since the term $(Z_oZ_L)/(Z_o+Z_L)$ gives the value of Z_o and Z_L taken in parallel which is designated by Z' in equation 3, the right-hand members of equations 3 and 6 are the same, and therefore

$$\frac{E_{B1}}{E_{B2}} = \frac{E_1}{E_2} \tag{7}$$

Equation 7 shows that within the approximations stated the laboratory test shows the effectiveness which the filter being tested would have in an apparatus circuit having the same value of Z_o and Z_L.

It is generally more convenient to use the second method which is to reduce the signal generator voltage in diagram *b*, filter removed, to give the same value of output voltage E_B as in *a*, filter in. The effectiveness is then given by E_A/E_C which is the same ratio as $(E_{B1})/(E_{B2})$. This is demonstrated as follows:

Equation 1 becomes $E_B = E_A \dfrac{Z_1Z_2}{Z_AZ_2}$ (1a)

Equation 2 becomes $E_B = E_C \dfrac{Z'}{Z_A}$ (2a)

Combining these equations we obtain

$$\frac{E_A}{E_C} = \frac{Z'Z_2}{Z_1Z_2} \tag{3a}$$

Referring to equations 3 and 7, it is evident that

$$\frac{E_A}{E_C} = \frac{E_1}{E_2} \tag{8}$$

This relation enables the filter effectiveness to be determined from the signal generator voltage calibration in which case the voltmeter on the output (E_B) is used merely as an indicator.

References

1. Methods of Measuring Radio Noise 1940, report of Joint Co-ordination Committee on Radio Reception of Edison Electric Institute, National Electrical Manufacturers' Association and Radio Manufacturers' Association. Edison Electric Institute publication G9, National Electrical Manufacturers' Association Publication 107, Radio Manufacturers' Association *Engineering Bulletin number 32*.

2. Measurements Pertaining to the Coordination of Radio Reception With Power Apparatus and Systems, C. M. Foust, C. W. Frick, AIEE Transactions, volume 62, 1943, June section, pages 384–91.

Manual Switches for Aircraft

R. A. MILLERMASTER
MEMBER AIEE

Synopsis: In the design and application of electrical control equipment the problem of obtaining complete field data and requirements is always present in some degree.

The problem is acute in branches of the electrical industry supplying aircraft control. Three factors contribute to the difficulty:

1. The tremendous engineering effort centered in the aircraft industry causes rapid technical changes that soon make accumulated data obsolete.
2. Technical data on utilization devices are not always available to either the aircraft or electrical manufacturer. The mushroom growth and technical advance of the aircraft industry have, in some cases, outdistanced laboratory equipment and personnel capacity so the data an electrical-control manufacturer would like to have are simply not available.
3. The secrecy surrounding many aircraft developments blocks the passing of information from the aircraft manufacturer to the electrical manufacturer.

The electrical-control manufacturer can meet this problem, in part, by making available complete performance data on switching equipment offered for sale. Properly chosen, these data enable the aircraft engineer to match control means with his electrical utilization device requirements.

In the preparation of such data the following considerations are of primary importance to both the user and producer of switches.

The functions of an aircraft switch may be classed broadly as follows:

1. To establish a circuit.
2. To maintain a circuit.
3. To interrupt a circuit.

Performance of these functions is importantly affected by the following characteristics of the load:

(*a*). Inrushes.
(*b*). Inductance.
(*c*). Current.
(*d*). Voltage.

IN establishing a circuit, the increasing order of difficulty shows:

(*a*). Inductive loads.
(*b*). Resistive loads.
(*c*). Lamp loads.

When a set of switch contacts closes, the circuit is seldom established without some disturbance (see Figure 1). The current magnitude at the time of this disturbance becomes a major factor in switch performance. Contact erosion results, caused by the arcing which normally accompanies such disturbance, and in extreme cases freezing or welding occurs with the possibility that the switch may immediately become inoperative through inability to open the freeze. In most switches the contact bounce that creates these disturbances ends within ten milliseconds, and the current magnitude for that period of time is of primary importance in connection with this first function of a switch, establishing the circuit.

(*a*). Inductive loads build up slowly, and the current for a time after the switch contacts close is less than steady-state value.

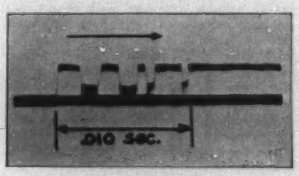


Figure 1. Switch contact bounce

For this reason damage to contacts is minimized.

(*b*). Resistive loads cause more damage in establishing the circuit than inductive loads do because of the substantially vertical front current increase. This means that any bouncing of contacts (with accompanying arcing) occurs at practically full steady-state circuit load instead of the fraction of steady-state current indicated in the preceding inductive-load discussion.

(*c*). Inrush loads are most severe in circuit establishment. The common forms experienced are lamp and motor inrushes. The former—because of their characteristic vertical front current increase, and because of the relatively slow decay of the inrush—are the most severe of any circuit-closing condition. Any switch bouncing is almost sure to occur at currents well above steady-state values. Motor inrushes are not comparably severe because the inductive component tips and rounds off the wave front in a manner so bouncing usually occurs before maximum inrush current is reached. Condensers have a steep wave front like resistance, but the circuit ordinarily has other limiting resistance.

The second function of the switch, maintaining the circuit, is mainly affected by the circuit characteristics of current and voltage. The passage of current across the internal resistance of a switch results in a wattage loss that must be dissipated without causing harmful temperature rises in either conducting or insulating members. Experience indicates that, if the continuous duty rating of a switch be taken as 100, the 15-minute, 5-minute, 1-minute, and 5-second ratings may be taken as 110, 150, 200, and 400, respectively, for the average switch used in aircraft circuits. Losses must also be limited to the extent necessary that excess voltage drop will not obtain. The circuit voltage (which may vary from supply voltage) strains the switch insulation, which must, under all operating conditions, be capable of restricting current flow to switch parts that are normally current-carrying members. Conducting paths to ground or opposite polarity result from voltage breakdowns, and such paths may carbonize and progressively develop more wattage until complete failure occurs. The stripping of conductor insulation at the switch requires the provision of adequate circuit insulation from terminal to terminal through the switch.

The third function of the switch, interrupting the circuit, is affected by circuit current, voltage, and inductance. Figure 2 shows a switch opening a resistance load of 30*A* at 30*V* and the same switch opening a highly inductive load of 25*A* at 30*V*. The arcing time for the inductive but slightly smaller load is more than 12 times that for the resistive load. The major watt-seconds loss is developed near the start of circuit opening even though a high-voltage kick develops just before the current reaches zero. This last kick, though occurring at so low current value that little wattage is involved is of importance because of the strain it places on circuit insulation and because it contributes, in some instances, to arc restriking or flashovers to ground.

In order that switch functioning under the previously described circuit conditions may be checked by laboratory tests it is necessary that voltage and current

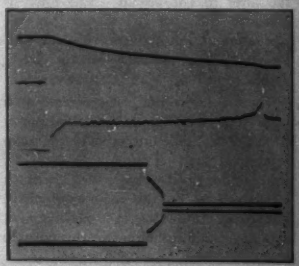


Figure 2. Current and voltage across switch contacts, 25 amperes inductive (above) and 30 amperes resistance (below) loads on 30-volt supply

Paper 43-130, recommended by the AIEE committee on air transportation for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21–25, 1943. Manuscript submitted April 30, 1943; made available for printing May 25, 1943.

R. A. MILLERMASTER is supervising development engineer for Cutler-Hammer, Inc., Milwaukee, Wis.

sources, along with elements to establish circuit components for inrush and inductive effects, be provided. A series of performance requirements, substantially formalized in specification *ANS*-20 is applied to test each switch intended for aircraft, establishing the following data:

1. Current-making capacity (10,000 operations).

(*a*). Lamp load (10 × hot filament current).

2. Current-breaking capacity (10,000 operations).

(*a*). Resistance load.

(*b*). Inductive load (using standard test inductors with L/R ration of 0.26).

3. Emergency break (50 operations inductive load).

4. Current-carrying capacity.

1*a*. The inrush circuit provided for determining current-making capacity uses a normally closed contactor which opens soon after (about 40 milliseconds) the switch under test closes (see Figure 3) and remains open until the switch under test opens. As shown in Figure 4, the switch under test opens zero load. This may be made a finite load, however, by shunting the break load across this normally closed contactor. The advantage of this circuit lies in the fact that the line of current increase is almost vertical, and a flat top holds the inrush at maximum value for approximately 40 milliseconds so that any switch closing disturbance occurs at peak current. The lockout-contactor type of circuit is a more severe circuit than usually found in practice, but it provides a test that may be duplicated in any laboratory and determines a switch rating that may be used safely with any kind of inrush load.

2*a*. The resistance-load test requires no special comment.

2*b*. The inductive circuit for this type of testing was co-operatively developed by the Army Air Corps and the Navy Bureau of Aeronautics, again with the aim of providing a circuit which could be duplicated in any laboratory and which would, at one time, test switches under conditions of sufficient severity to guarantee satisfactory performance in any of the so-called "highly inductive" aircraft circuits. These circuits include brake coils, solenoids, relay and contactor coils, and so forth.

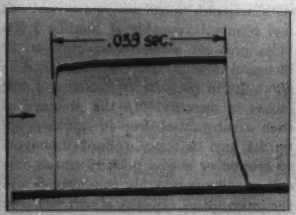
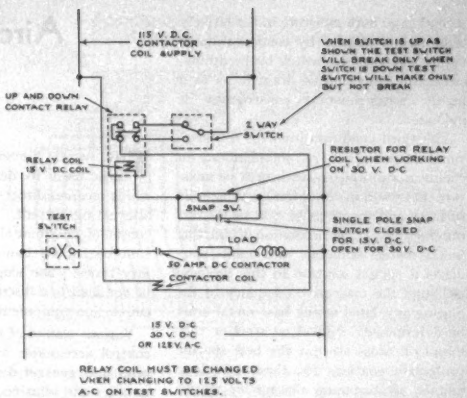


Figure 3. Wave form. Standard inrush circuit

Figure 4. Line diagram of standard inrush circuit


115 V. D.C. CONTACTOR COIL SUPPLY
WHEN SWITCH IS UP AS SHOWN THE TEST SWITCH WILL BREAK ONLY WHEN SWITCH IS DOWN TEST SWITCH WILL MAKE ONLY BUT NOT BREAK
UP AND DOWN CONTACT RELAY
2 WAY SWITCH
RELAY COIL 115 V. D.C. COIL
RESISTOR FOR RELAY COIL WHEN WORKING ON 30 V. D-C
SNAP SW.
TEST SWITCH
SINGLE POLE SNAP SWITCH CLOSED FOR 115 V. D-C OPEN FOR 30 V. D-C
LOAD
50 AMP. D-C CONTACTOR COIL
115 V. D-C 30 V. D-C OR 115 V. A-C
RELAY COIL MUST BE CHANGED WHEN CHANGING TO 115 VOLTS A-C ON TEST SWITCHES.

So duplication could be readily attained, the following inductor elements are defined:

1. Iron circuit.
(*a*). Lamination dimensions.
(*b*). Lamination material.
(*c*). Magnetic saturation.
(*d*). Air gaps.
2. Copper circuit.
(*a*). Coil dimensions.
(*b*). Ballast resisters.

The stored energy of the magnetic circuit and the rate at which this stored energy is released were made the subject of a study based on tests conducted on a number of solenoids, relay coils, and so forth, now in use. Voltage surge, current decay, and arcing time were the main measures of equivalence and were determined with the circuit controlled by the same switch type in all cases. The standard test inductor shown in Figure 5 resulted.

The functioning of a switch is basically dependent on the characteristics of the electrical circuit to be controlled, but the physical characteristics of the surrounding atmosphere and supporting structure are, in many cases, of equal importance.

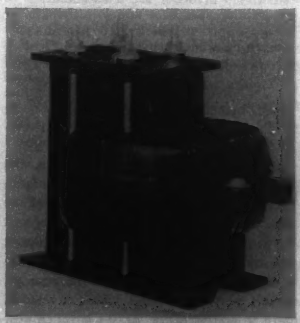


Figure 5. Standard test inductor

Physical conditions which at times assume such importance are:

1. Ambient temperature.
2. Humidity.
3. Chemical atmosphere or sprays.
4. Accelerations.
5. Altitude or pressure.

The ambient temperature, in the low range of 50 and 60 degrees Fahrenheit below zero may interfere with the mechanical action of a switch by congealment of lubrication, while the high range of 150–175 degrees Fahrenheit accentuates the problem of temperature control in current-carrying elements and insulation.

The second physical condition substantially affecting switch performance is the presence of humidity or moisture, either through exposure of the switch to direct wetting action by rain, splashing, and so forth, or by breathing air into the switch interior under conditions of high relative humidity with variable temperature. In the first case the switch is best protected by the use of water-resistant gasketing and joint constructions. In the

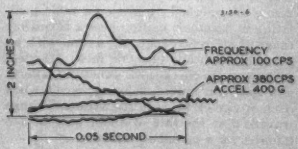


Figure 6. Panel subjected to shock test
With eight-pound shutter on bakelite panel at center

second case, with moisture in a relatively tight switch interior by condensation of vapors entering the switch by breathing, either the provision of drain holes or a highly water-resistant construction is indicated.

The third condition involves the presence of salt spray or combinations of chemical atmospheres with heat or moisture that result in deterioration at metallic surfaces and junctions of case or mounting elements. The elimination of abutting unlike metals or metals with unlike plating is a partial solution to this problem although the protective adequacy of the plating as related to the base metal must be determined. Nickel on steel or cadmium on brass are not the best specific protective coatings for these two base metals, yet cadmium plating for assemblies of steel and brass parts is a good plating because the more readily corroded material (steel) is protected and unlike metallic abutments are not present. Choice of protective metallic coating must also recognize the by-products resulting from protective action. For instance, zinc, in the presence of moisture, forms zinc hydroxide and carbonate, bulky salts of high electrical resistance, that would cause failure in closely fitting assemblies or at the electrical contacts of a switch. Cadmium, in a tight enclosure and at high temperature, in presence of some insulating varnishes and oils, such as tung and chinawood oils and air dry phenolic varnishes, may "bloom," forming a bulky salt of high electrical resistance.

The fourth condition affecting switch performance results from mechanical acceleration which may occur in the following forms:

(*a*). Linear.

(*b*). Vibrational.

(*c*). Shock.

(*a*). In the first form a constant linear acceleration and its effect on switches can be readily computed and measured by laboratory tests. A rotating table may be used to generate this acceleration in accordance with the formula:

$$\text{Acceleration} = Kx(\text{RPM})^2 \times R$$

(*b*). In the second form of acceleration free vibrations that may be induced by vibration in the plane frame and structural elements are checked by test on a table oscillating in harmonic motion over a frequency range of 10 to 60 cycles per second with an over-all amplitude of 0.060 inch. Devices under test are checked for structural failures and electrical failures (closing circuit when open or vice versa) with the frequency range traversed at the rate of about once in 3–5 minutes for a period of one hour.

(*c*). In the third form of acceleration, shock resulting from landing, shell burst, and so forth, transmits itself to the switch through plane structure and switch mounting means. The motion, velocity, and accelerations involved are a combination of effects discussed in *a* and *b*, although the energy imput to the switch is ordinarily greater than in either *a* or *b*. See Figure 6 showing the time—motion trace of a panel subjected to a high-shock test. Manual switches have been tested in a pendulum shock machine. Consideration is being given the use of a drop machine suggested by the Bureau of Standards.

In these three acceleration tests, the measure of electrical failure is a self-maintaining electrical indicator set to pick up in four milliseconds and drop out in four milliseconds. A device like a bomb rack solenoid requiring eight milliseconds to initiate armature movement, would not be affected when in circuit with a switch which passes a shock test with four millisecond indicating means.

The fifth physical condition affecting switch performance is altitude or pressure. Air-gap dielectric strength becomes a matter of definite concern. The sparking potential, a function of gap and pressure, becomes a major factor, and switches with normal forms of air gaps at contacts and terminals, capable of holding 2,500 volts pressure across these gaps at 29 inches of mercury, have by test failed at 800 volts in pressure equivalents of five inches of mercury. In the presence of such a substantial drop in sparking potential any tendency toward flashovers to ground or across polarity during circuit opening is severely emphasized, and the interrupting capacity of switches, particularly on inductive circuits, must be carefully determined.

Aircraft Inverter Construction

C. T. BUTTON
ASSOCIATE AIEE

THE word "inverter" is a generic term used to designate any device which receives direct current and delivers alternating current. Such a device may consist of electronic elements, or vibrating contacts, or mechanical choppers, or rotary types. The scope of this paper will be confined to a discussion of rotary-type conversion equipment.

Various classes of rotary inverters and control accessories will be listed with a brief and general description of characteristics and relative merits, viewed from the standpoint of the requirements of military aircraft. A statement of what the principal requirements are is first in order.

Operating Requirements

An aircraft inverter must operate on the d-c supply of the plane, which usually is obtained from generators driven from the main engines. These generators may be of 50-, 100-, or 200-ampere rating; and in a four-engine bomber there are usually four 200-ampere generators connected in parallel while in normal flight. The d-c bus voltage is maintained fairly constant by means of carbon-pile regulators controlling the generator fields. A battery usually floats on the bus.

The inverter is connected to the d-c bus through a solenoid-operated switch. For purposes of inverter design, the voltage delivered to it is considered to be 27.5 volts, with maximum variation of plus or minus 2.5 volts. In routine flight, carbon-pile voltage regulators restrict the d-c voltage variation to less than one volt, except for momentary transients.

With an input voltage at any point from 25 to 30 volts, the inverter should be capable of starting and carrying full rated load continuously. An operating life of at least 1,000 hours without major overhaul is expected, with starting as frequent as once per hour.

Output ratings may be anywhere from 6 to 3,000 volt-amperes, with an ever-present possibility of increased loads in the future requiring larger sizes. Effort has continuously been made and will continue to be made to standardize on rated loads or sizes. In view of the fluidity of the load requirements and resulting necessity of modifying specifications on actual conversion units procured from time to time, a formal tabulation of ratings will not be listed. Formalized specifications are available, one of which is the United States Army Specification 94-32270. These formal specifications are amended from time to time as need requires.

In order that this discussion may be self-contained however, three sizes of

Paper 43-127, recommended by the AIEE committee on air transportation for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21–25, 1943. Manuscript submitted April 5, 1943; made available for printing June 2, 1943.

C. T. BUTTON is sales engineer for the Holtzer-Cabot Electric Company, Boston, Mass.

inverters currently used in large quantities will be mentioned, the ratings of which are as follows:

Rating	Output at 400 Cycles: 26 Volts 40 Per Cent Power Factor	115 Volts 90 Per Cent Power Factor	Class*
250 va.	60 va.	1 phase	C
750 va.	250 va.	1 phase	D
1,000 va.	250 va.	1 phase	F
	750 va.	3 phase	

* See tabulation under "Classification of Basic Types."

The 26-volt output is primarily intended for electrical-instrument supply but may be used for other single-phase loads such as fluorescent lighting. The voltage requirements are not exacting on this circuit, and automatic regulation has not been considered necessary.

The 115-volt circuit may be used to supply fluorescent lights, automatic radio compass, motor loads, supercharger regulators, automatic pilot, and bombsight. In the case of some of these loads, the voltage requirements are not exacting, and the percentage variation experienced on the d-c bus may be tolerable. In such case, an inverter which may be regarded as a transformer (if of sufficiently low internal impedance) may be a simple and satisfactory mechanism.

However, as more precision equipment is developed and put into use, and with transient voltage fluctuations occurring because of high momentary current to gun-turret motors, need for automatic control of the 115-volt 400-cycle source becomes apparent.

As a broad statement, the voltage on that circuit should not exceed 120 nor be less than 110 at any load from no load to full load, and at any d-c input voltage from 25 to 30. However, modulations or transients or poor wave form may be objectionable in some instances. Since no practical source will deliver a pure sine wave at exactly 115 volts 400 cycles in service, and since the greater precision demanded the more complicated the equipment becomes, the construction and acceptance of the most practical machine in any particular case necessarily becomes a matter requiring engineering cooperation. In other words, there are so many factors involved that the procurement engineers cannot say "Here are our specifications. Any machine meeting them is acceptable, and contrariwise." Likewise, the manufacturers' engineers cannot say "Here is the best possible equipment for the job; that's all there is."

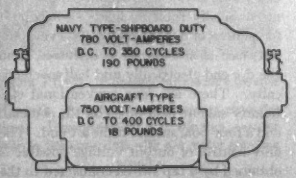
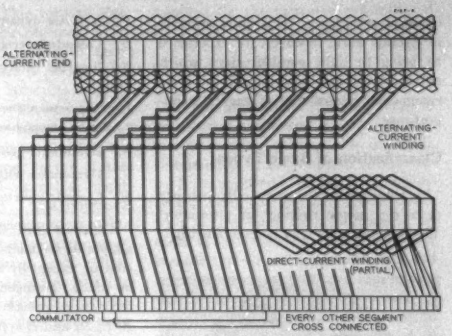


Figure 1. Comparison of size and weight of units built for aircraft and shipboard duty

Figure 2. Cascade inverter — schematic diagram of armature connections



Specified weights for various inverter ratings will not be listed, as they are changing from time to time. Refinements in design make lighter weight machines available. However, a contrary tendency toward heavier weights also inevitably results from requirements for more accurate control of output voltage and frequency. As an illustration of weight trend, one inverter of the inductor-dynamotor type was in use in 1939, weighing 18 pounds and capable of delivering 250 volt-amperes. A cascade-type inverter was designed in 1940 having the same weight and delivering 750 volt-amperes. A comparison of the latter with a motor-generator set for use on board ship is given by Figure 1, where the two are shown with outlines drawn to the same scale.

Later developments, however, required addition of radio-interference filter and control accessories, adding a few pounds.

The importance of light weight in aircraft equipment needs no argument. One pound of fixed weight requires another pound of structure and fuel to carry it.

Likewise, the importance of efficiency may be emphasized by the following approximate data:

An aircraft engine consumes about 0.5 pound of fuel per horsepower-hour. The generators are roughly 75 per cent efficient. Hence, 1,000 watts of inverter input requires the consumption of about one pound of fuel per hour. Every 100 watts saved is worth a pound of fuel on a ten-hour flight. That pound of fuel might take the airplane another half mile. It might be said as a generality that 100 watts of additional inverter losses would necessitate a certain additional weight of generator capacity. In a practical case, this capacity may be already available.

All things considered, perhaps a weight saving of one pound in an inverter is worth while if the losses are not increased as a result by more than 100 watts. This figure is by no means definite, however, and has not been set up as a design criterion.

It is no simple problem, nor can any definite general answer be given, as to what point it is best to stop at in weight reduction on account of loss in efficiency or possible sacrifice in reliability. Likewise, extremely light weight may mean high internal impedance and hence high-voltage regulation. High speed makes light weight possible but reduces bearing life and decreases reliability.

These are all matters which should have the benefit of sound engineering judgment. The most sound judgment is

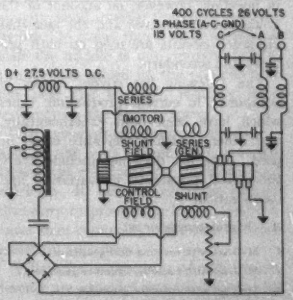


Figure 3. Schematic diagram of 1,000-volt-ampere dynamotor-generator type

based on experience. It is quite common in aircraft work, however, for experience to bring to light considerations which either were not anticipated or were erroneously regarded as of negligible importance.

Classification of Basic Types

A rotary inverter essentially consists of a d-c motor driving an alternator. The two elements may be combined in a single magnetic circuit, the most intimate combination being an inverted rotary converter. The latter is analogous in some degree to an autotransformer, where primary and secondary conductors are common. A simple rotary converter cannot be used to fulfill the requirements in question, however, on account of the voltage ratio involved and the fact that grounded circuits are used on both primary and secondary.

Figure 4. Centrifugally operated contact-making speed governor, cover removed

Parts shown in lower view include two rotating pieces, bakelite button for transmitting thrust, and stationary contact unit with adjusting screw

The following list covers classes of equipment in current production, types which have been built experimentally, and others which conceivably could be used. The list does not include every theoretical possibility of variation and combination.

A. Motor-generator set

1. M-G set with rotating field generator
2. M-G set with rotating armature generator
3. M-G set with inductor generator
4. M-G set with permanent magnetic generator

B. Dynamotor

C. Inductor-dynamotor

D. Cascade inverter

E. Inverted rotary converter with transformer

1. Separate transformer
2. Rotating transformer

F. Dynamotor-generator

G. Dynamotor with booster

H. Cascade inverter with booster

Types *A*4, *B*, *C*, *D*, and *E* are not adaptable to independent output voltage control, except by a separate series boost or buck arrangement in primary or secondary circuits. The behavior of *B*, *C*, *D*, and *E* types may be compared with that of a transformer, where output voltage is proportional to input voltage less internal impedance drop.

Considering the other classes where automatic control of output voltage may be obtained by field regulation, these may in turn be divided into two groups—those with slip rings and those without.

*A*1, *A*2, *F*, and *G* have slip rings.

*A*3 and *H* do not have slip rings.

Of these latter two groups, those without slip rings will weigh perhaps 25 to 35 per cent more than those with slip rings, all design factors being on an equivalent basis.

Another theoretical possibility which would fall in the last group is an inductor dynamotor with inductor-type booster generator. The practical advantages of such a combination is questionable.

The motor-generator set with inductor generator, class *A*3, has the advantages of ruggedness and reliability, since it has no conductors on the generator rotor and no slip rings. For 400-cycle service where light weight and hence high speed is required, the generator will probably be the twin-stator type with single stationary field coil in the shape of an annular ring lying between the two stators. The generator rotor will have three salient poles or six effective poles on each end, for 400 cycles at 8,000 rpm. The direction of the flux is centrifugal in one stator and centripetal in the other, and crosses each air gap in three rotating bands of high and essentially constant density at the rotor pole faces.

Figure 5. Centrifugally operated carbon-pile speed governor

Figure 6. Physical arrangement of resonant-circuit feed-back speed-control equipment including capacitor, reactor, and rectifier shown in Figure 3

The inductor dynamotor, class *C*, has a single armature with salient teeth or poles. The a-c winding lies in slots in the pole faces, the field poles otherwise being like those of an ordinary two pole d-c motor. This mechanism is essentially a merging of the motor-generator set with inductor generator into a single magnetic circuit. This combination does not produce a net gain necessarily, since control of output voltage (except in steps by a tap switch) is lost, and a speed of over 4,000 rpm for 400 cycles would result in difficulties. For some purposes however, such a machine has been extensively used with satisfactory results.

The cascade inverter consists of two parts in one frame and is physically similar to a two bearing motor-generator set. The d-c end acts as an inverted rotary converter built for 200 cycles, multiphase output. This output is delivered to the rotor of the a-c end, which is slotted and wound similar to the d-c armature, except that the 200-cycle phase rotation is reversed, as shown by Figure 2. Thus, the a-c end operates as an a-c excited generator, with combined electrically and mechanically rotating field. When built for a speed of 6,000 rpm for 400-cycle output, half of the energy is delivered from the d-c end electrically and half mechanically. There are four conventional stationary salient field poles on the d-c end, and a four-pole stator on the a-c end. The only control of output voltage possible is obtained by a tap switch connected to the output stator.

An inverted rotary converter with ro-

tating transformer, class *E2*, has been built, the advantages conceived being that the (circular three-legged) transformer would be well cooled; and six-phase low voltage could be carried directly to the transformer primary winding. This particular machine was intended for three-phase output only and hence had three slip rings.

The dynamotor-generator, class *F*, was designed to deliver both three-phase and single-phase output, and it was desired not to have the single-phase load unbalance the three-phase voltages. Accordingly, the motor was designed for operation at 8,000 rpm with six poles, and a dynamotor winding superimposed to deliver single-phase 400 cycles through slip rings. Figure 3 is the schematic diagram. The generator is a three-phase rotating-armature type. Hence this machine is a combination of class *A2* and class *B*.

A dynamotor with booster, class *G*, has been built for three-phase output only. A dynamotor may be somewhat lighter than a motor-generator on account of having a single magnetic circuit, utilizing the same flux for both motor and generator conductors. A small generator adequate to supply the differential energy required to maintain constant output voltage is provided, acting as a booster. The greater part of the energy conversion takes place in the dynamotor. This was built in two and three kilovolt-ampere sizes and is probably the lightest type of inverter of the slip ring class for this particular duty.

A cascade inverter with booster, class *H*, has been built, which is a class *D* (cascade) inverter with tertiary element in the 200-cycle circuit between the d-c and a-c armature cores. This tertiary element is a small 200-cycle generator with four salient field poles and with each armature coil connected in series with the 24-wire 12-phase 200-cycle output from the d-c armature. The series boost effect at 200 cycles was added at an advanced phase angle so that with a lagging 400-cycle load the power factor of the 200-cycle load on the d-c armature might be brought near unity. The objective was to increase the efficiency since an inverted rotary converter operates most efficiently on a resistance load. However, the net over-all gain of this boosting at an advance angle is dubious, since the tertiary element must then have more capacity than would be the case for in-phase boosting.

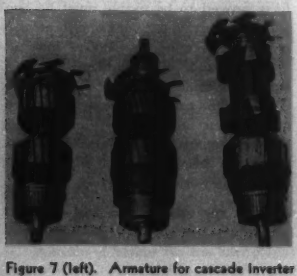


Figure 7 (left). Armature for cascade inverter

(Center). Armature for dynamotor-generator type. Twenty-six-volt a-c winding can be seen in the same slots with d-c motor armature winding

(Right). Rotating element including motor armature and rotor for inductor generator

Figure 8. Inverter made by the Leland Electric Company

An inverter with inductor-type generator is being considered, with one stator having a three-phase winding and the other supplying the single-phase load.

At least four of the classes listed are in current use in large quantities.

As is frequently the case, there would be no particular problem involved if one type of machine had all of the advantages (minimum number of brushes, light weight, reliability, and independent sources of single- and three-phase output). Many practical considerations enter, and it may be that, even for a single well-defined set of load requirements, it will be difficult if not impossible to arrive at a universally accepted decision as to the best machine for the job.

The problem of obtaining satisfactory brush operation at high altitudes is now generally recognized in the electrical industry as a serious one. The approach to this, in so far as inverter design is concerned, has been to study the problem intensively in itself but simultaneously to develop inverter designs without generator slip rings. As indicated previously, a sacrifice in weight must be accepted in payment for the increased reliability of an inverter with no generator brushes.

Construction Details

Inverters for aircraft duty are made in two-bearing open-type frames. Specifications require openings to be small. Internal fans, either propeller or centrifugal type, are used. Sealed or labyrinth-type shielded bearings are generally used, with no provision for relubrication. A speed of 8,000 rpm is commonly used, but cascade types running at 6,000 rpm and inductor types at 4,000 are also widely used. The inverters must be capable of operating in any position, be built to withstand shock and vibration, and be capable of operating in any outdoor tem-

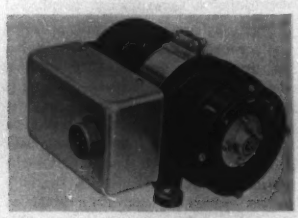


Figure 9. Inverter of Eclipse aviation division, Bendix Aviation Corporation

perature and pressure encountered on the surface of the earth and up to 40,000 feet above it.

Hollow shafts are used in many of the inverters for weight reduction. End bells are made of magnesium or aluminum. Armature and stator laminations have holes or slots where all metal not definitely needed for carrying flux or for mechanical purposes is removed.

Armatures are, of course, dynamically balanced. In the case of some of these machines where the armatures are long, the shaft not too heavy, speed high and air gap small, special procedure may be required to insure that a static unbalance near the middle is not compensated by two weights added on the opposite side but near the bearings, resulting in a tendency for the shaft to spring.

With good air circulation easily obtainable at the high speeds used, and the losses kept relatively low to obtain good efficiency, it has not generally seemed necessary to provide for higher temperatures than commonly dealt with in other electrical apparatus.

Filters for suppression of radio interference are provided integral with the inverters.

Electrical connections are made with

Figure 10. Holtzer-Cabot inverter

standardized *A-N* aeronautical-type fittings.

Frequency Control

Figure 4 shows a centrifugally operated contact-making speed governor which has no slip rings or brushes. The rotating element consists of a yoke carrying a spring which is deflected by the centrifugal force resulting from two weights. The axial motion of this spring is transmitted to contacts which are a part of the stationary unit by means of a "bakelite button" which engages with a dimple in the spring at the center of rotation. The points are of molybdenum-silver. The usual capacitor and resistor are provided across the contacts. The familiar Lee-type governor is also used.

A carbon-pile speed governor which is actuated by centrifugal force has been developed, the operation of which is superior to that of the contact-making governor in some respects. This is shown by Figure 5.

A resonant circuit feed-back speed-control circuit, Figures 3 and 6, is used on one inverter. This has a series circuit tuned for a peak at slightly over 400 cycles. In series with the capacitor and reactor in this circuit is a dry-disk rectifier. The d-c terminals of this in turn supply a control field on the motor. Consequently, as the output frequency approaches 400 cycles, the current in this control field rapidly increases, and the speed stabilizes. The rectifier delivers to the control field direct current plus an 800-cycle component. In order to maintain substantially constant flux, each field pole is provided with a heavy copper shading coil. Taps are provided on the reactor to compensate for manufacturing variables in the inverter and the capacitor.

Electronic controls have been developed for both speed and voltage. It would be quite possible to obtain extremely accurate frequency control by this means, if required, by using a tuning fork as the reference. Here again however, the greater the precision required

Figure 11. Inverter manufactured by General Electric Company

the more susceptible to trouble the apparatus becomes—as well as being more bulky.

Voltage Controls

It is believed that no good purpose will be served by elaborating on theoretical possibilities for automatic voltage control. A long discussion could be presented, starting with the Tirrill-type regulator and leading up to electronic-type precision controls. These devices would include multifinger contact-type regulators, saturated reactors, and various others. The carbon-pile regulator, however, has come into very general use both for controlling the main d-c generators and for regulating the 400-cycle inverter output as well. Present indications are that it has no inherent serious disadvantages and that it produces satisfactory results. In applying a carbon pile to an inverter, over-all temperature compensation must be obtained, including the rectifier in the circuit supplying the actuating solenoid from the 400-cycle circuit being regulated.

Radio-Interference Filter

Specifications require the radio-frequency component of voltage in any input or output conductor of the inverter to be less than 50 microvolts at any frequency from 0.2 to 20 megacycles. For the purpose, it is common practice to use a π-circuit filter in each conductor. The reactance should not be so large as to cause excessive voltage drop in the 400-cycle conductors, and here air-core chokes are commonly used. Textbook rules for the most efficient design of choke result in minimum space and weight. Capacitors should be no larger than necessary, both because of space and weight considerations and the effect of the leading current on the no-load voltage where voltage regulators are not used. Great care must be used in designing a filter as to arrangement of components, length of leads, and method of grounding.

Conclusions

While continuous effort has been made to standardize ratings and performance requirements, this has been difficult. Load requirements change rapidly, and the way must be left open for refinements of inverter design.

A motor with automatic speed control driving a generator with automatic voltage control appears to be the most desirable general type for most purposes.

Production of existing designs which have proved to be usable must be continuously carried on; and simultaneously new designs must be studied and advantages and disadvantages weighed. Interchangeability must be considered. Also, designs cannot be changed too frequently on account of maintenance problems, spare parts for aircraft components now being carried at many points around the world.

Fundamental Principles of Amplidyne Applications

F. E. CREVER
ASSOCIATE AIEE

Synopsis: The Amplidyne generator has been widely applied and is recognized as an important device in the electrical industry. Since it is used primarily as a power amplifier in regulating systems, the requirements of an amplifier for this use are analyzed, and the characteristics of the Amplidyne generator are compared in this paper with these requirements.

Owing to the large number of distinct windings of the Amplidyne, it is desirable to follow a consistent practice in terminal markings and polarities. Proposals for this purpose are outlined in the paper, and typical values of amplification for different output ratings are given.

Service experience and an application typifying the use of the Amplidyne are discussed, so that the reader may become familiar with the device and its uses.

SINCE its introduction into the electrical industry, the Amplidyne generator has been found useful in a large variety of applications. The chief use has been in closed-cycle controllers or regulating systems as a power amplifier. In order to see why the Amplidyne is particularly adaptable and useful in regulating systems, it is desirable to review and analyze the characteristics of the regulating system to determine the requirements of an amplifier for use therein.

The Regulating System

A closed-cycle control system or regulating system is one in which the controlling agency is actuated by some function of the final output in such a manner as to minimize any deviation of the output from an ideal value.

There are three fundamental elements of such a system, namely:

1. A standard of ideal performance against which the output to be regulated can be compared.
2. An amplifier to amplify any deviation of output from the standard.
3. A means of feeding the amplifier output into the system in such a manner as to minimize the deviation.

Paper 43-125, recommended by the AIEE committee on air transportation for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21–25, 1943. Manuscript submitted April 9, 1943; made available for printing June 7, 1943.

F. E. CREVER, engineer, is with the General Electric Company, Schenectady, N. Y.

Many factors need to be considered in devising a regulating system, and these have been outlined in a previous article.[1] It is not the purpose here to elaborate on these factors any more than necessary to establish a basis for analysis of the amplifier requirements in the system and to show how such an analysis acts as a guide in evaluating various proposed amplifiers for this use.

The first element of the regulating system, namely, the standard of performance, may be either a primary or a secondary standard and must be of like physical kind to the quantity to be compared with it. It is very often necessary to transform the quantity to be regulated into the same form as the standard for comparison. It can be readily understood that standards and transformations can most readily and economically be obtained at low power levels.

The third element of the system, the means of feeding the amplifier output into the system, may, and in most cases does, require a very considerable amount of power.

It is obvious that a high degree of power amplification is an important requirement for an amplifier to be used in a regulating system.

Stability is another primary requirement. It is beyond the scope of this article to establish mathematically the requirements for stability of the regulating system. Instability can be explained by the existence of a series of time delays in the system. In general, the greater the number of time delays in series and the higher the amplification the greater will be the tendency to oscillate. Also, in a system with three or more simple exponential time delays in series, the more nearly the time delays equal each other in magnitude the greater will be the tendency to oscillate. Since in the usual industrial power apparatus the time delay of the final controlled element is appreciable, it is generally important to reduce to a minimum the time delays in the system prior to the final one. From these considerations, the second desirable characteristic of the amplifier is as short a time delay as possible between input and output.

One thing that has not been generally recognized is that the closed regulating circuit affects the response time of the system as well as minimizing the deviation between the standard and the system output. In this respect, a regulating system is very similar to an inverse feedback amplifier.

Analysis of Simple Regulating System

Figure 1 illustrates a very simple regulating system with one time delay. For purposes of analysis, assume that up to a time $t=0$ the standard voltage has been 0 and is instantly made equal to E_S at time $t=0$. Furthermore, assume the amplifier and generator amplifications to be linear over the range of voltage considered.

Let

R_1 = generator field resistance
L_1 = generator field inductance
K_1 = generator armature voltage per field ampere
M_1 = amplifier amplification

$T_1 = \frac{L_1}{R_1}$ generator field time constant

$$E_1 = -M(E_R - E_S) = (R_1 + L_1 p) i_1$$

$$E_R = K i_1$$

$$-ME_R + ME_S = (R_1 + L_1 p)\frac{E_R}{K_1}$$

$$\frac{E_R}{K_1} R_1 (1 + T_1 p) + ME_R = ME_S$$

$$E_R = \frac{K_1 ME_S}{R_1\left(\frac{MK_1}{R_1} + 1 + T_1 p\right)}$$

Let

$\alpha = \frac{K_1 M}{R_1}$ = over-all system amplification

Then

$$E_R = \frac{\alpha E_S}{\alpha + 1}\left(1 - \epsilon^{-\frac{(\alpha+1)t}{T_1}}\right)$$

If we had merely applied a voltage E_1 to the field of the generator sufficient to bring the output voltage without the regulating system up to a value equal to E_S, the equation for E_R would have been

$$E_R = \frac{E_1 K_1}{R_1}\left(1 - \epsilon^{-\frac{1}{T_1}t}\right)$$

Thus, we see that the use of the regulating system not only minimizes deviation from the value of the standard but has reduced the time delay of voltage build-up or effectively decreased the time constant in the ratio of $\alpha + 1$ to one.

This analysis assumes linearity of amplification, and it is to be noted that if the voltage output of the amplifier is limited,

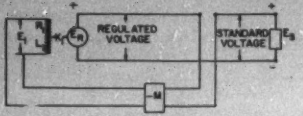


Figure 1. Simple regulating system

the response will be determined by the maximum voltage available at the generator field.

The Amplidyne

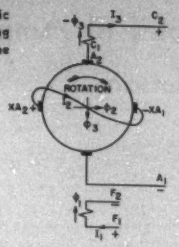
The Amplidyne has been described in detail in other articles.[2-4] It is here desired to point out the features of its design which make it outstanding in its performance.

A review of the operation is desirable to this end. Figure 2 shows a two-pole d-c armature with two pairs of brushes in quadrature. The frame is omitted from the diagram for simplicity, and the assumption is made that commutation is ideal. A flow of current I_1 in the control field F_1F_2 in the load axis creates a load-axis flux ϕ_1. The armature conductors cut this flux, and a voltage E_2 is generated in them to send current I_2 through the brushes of the short-circuit axis. The flow of armature current I_2 through the short-circuit axis of the armature develops a distributed magnetomotive force and flux ϕ_2 in the short-circuit axis. Rotation of the armature in this field generates a voltage E_3 at the load-axis brushes. The magnetomotive force of the armature caused by current I_3 is in opposition to the magnetomotive force of the load-axis control field. However, there is a distributed compensating field which neutralizes the armature magnetomotive force caused by current I_3. Only a very small magnetomotive force is required in the load-axis control field to cause generation of the required voltage and current in the short-circuit axis to give full output voltage at the load terminals. Only a small generated voltage is necessary in the short-circuit axis, and yet the full voltage of the armature is available for forcing a rapid rise or decay of flux ϕ_1.

Analogy and Analysis of Time of Build-Up

The Amplidyne combines into one machine two stages of amplification, each stage of which has a very small time delay. The first stage of amplification is from the load-axis control field to the short-circuit axis, and the second stage is from the short-circuit axis to the load terminals. For purposes of approximate

Figure 2. Schematic diagram illustrating operation of the Amplidyne



analysis, it is as though two d-c generators were in series and with the first generator just as large as the second as regards voltage output capability. This is illustrated in Figure 3.

Let a unit voltage E_1 be suddenly applied to the control field.

Let $T_1=\dfrac{L_1}{R_1}$ $K_1=$ volts E_2 generated per field ampere i_1

$K_2=$ volts E_3 generated per field ampere i_2

$T_2=\dfrac{L_2}{R_2}$

Then

$$E_1=(R_1+L_1p)i_1$$

$$E_2=K_1i_1=\frac{K_1E_1}{R_1+L_1p}=(R_2+L_2p)i_2$$

$$E_3=K_2i_2=\frac{K_1K_2E_1}{(R_1+L_1p)(R_2+L_2p)}$$

$$E_3=\frac{K_1K_2E_1}{R_1R_2(1+T_1p)(1+T_2p)}$$

The solution of this is

$$E_3=\frac{K_1K_2E_1}{R_1R_2}\left[1+\frac{T_1}{T_2-T_1}\,\epsilon^{-\frac{1}{T_1}t}-\frac{T_2}{T_2-T_1}\,\epsilon^{-\frac{1}{T_2}t}\right]$$

Figure 4 is a plot illustrating the voltage rise in such a circuit having constants as follows:

$T_1=0.058$ second $\quad T_2=0.092$ second

These are values taken from a typical 1,500-watt 250-volt 1,750 rpm Amplidyne. The time delay T_1 is for a field occupying 25 per cent of the field coil space and capable of carrying continuously ten times the current required to excite the machine to 80 per cent voltage at rated load. The time delay T_2 is on a machine with a series field in the short-circuit axis which is connected in the armature circuit of the short-circuit axis.

From this analysis, it is evident that the Amplidyne is an ingenious method of obtaining two-stage amplification with a fast response in a single unit. A number of independent load-axis control field windings can be used, so that the resultant control ampere turns will represent the algebraic sum of several independently selected functions.

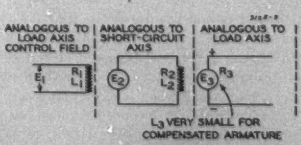

ANALOGOUS TO LOAD AXIS CONTROL FIELD
ANALOGOUS TO SHORT-CIRCUIT AXIS
ANALOGOUS TO LOAD AXIS
L3 VERY SMALL FOR COMPENSATED ARMATURE

Figure 3. Two-machine equivalent of the Amplidyne

Circuit Diagrams

To take full advantage of these possibilities and to avoid confusion in circuit diagrams, the symbols shown in Figure 5 have been found convenient. These symbols may be used as a guide for any combination of field windings. Connections of typical machines are shown in the diagram, and it can be seen that they are relatively simple. The only external connections are those of the various load-axis control fields and the power output leads.

Terminal Letters and Nomenclature

The same general rules are used for designating Amplidyne terminals as those in use for other d-c machines. The prefix X is added to the terminal markings of all windings which magnetize in the short-circuit axis, while the windings which magnetize in the load axis are marked without a prefix. See Figure 5 for detailed definitions of the various symbols.

Throughout the paper, the terms *load*

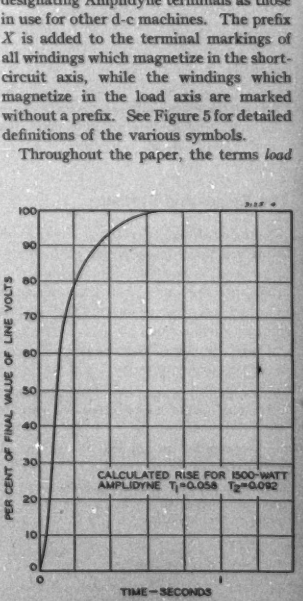


Figure 4. Response curve of typical Amplidyne generator

axis and *short-circuit* axis are used to describe the two axes. Other publications have also referred to the *load axis* as the *secondary axis* and the *direct axis*, and to the *short-circuit axis* as the *primary axis* and the *quadrature axis*.

Polarity

Amplidynes are so marked that for current which flows from the lower to the higher subscript terminal, in any of the control fields which magnetize in the load axis, the polarity of the terminal A_1 of the armature winding of the load axis is negative. This is true for both directions of rotation. Refer to Figure 5 for a detailed explanation of various windings.

Methods of Rating

Amplidyne generators are rated in kilowatts output, the product of rated voltage and rated current. It has been found desirable to select the voltage rating so that the saturation curve is essentially a straight line up to 80 per cent of rated voltage, and to provide a ceiling voltage approximately equal to 120 per cent of rated voltage. Typical saturation curves are shown in Figure 6. Usually, amplidyne generators are designed for 40 degrees centigrade temperature rise at rated voltage and current and to withstand a 200 per cent current peak momentarily at rated voltage. The machines should preferably be subjected to not more than 150 per cent rated current at rated voltage, tapering to 250 per cent at zero voltage.

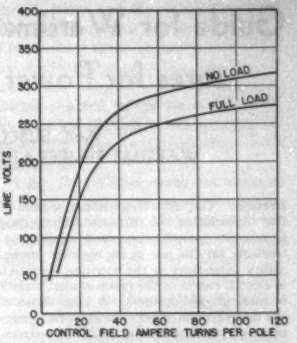


Figure 6. Typical saturation curves for 1,725 rpm 250-volt Amplidyne

The control field excitation requirements for typical 1,800-rpm Amplidyne-generator ratings between $^1/_2$ and 25 kw vary from 0.25- to 0.75-watt excitation (in one-fourth field space) with rated current output and 80 per cent rated volts; giving power amplifications (for one-fourth field space) from 2,500 to 40,000

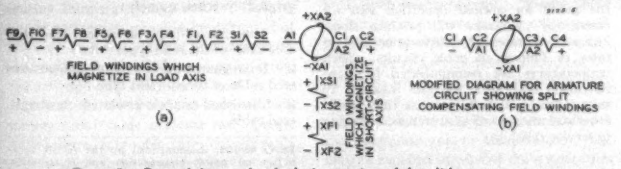

FIELD WINDINGS WHICH MAGNETIZE IN LOAD AXIS
(a)
FIELD WINDINGS WHICH MAGNETIZE IN SHORT-CIRCUIT AXIS
MODIFIED DIAGRAM FOR ARMATURE CIRCUIT SHOWING SPLIT COMPENSATING FIELD WINDINGS
(b)

Figure 5. General diagram for clockwise rotation of Amplidyne generators

1. Compensating field windings

The compensating field windings, C_1C_2, are always connected in series with the load axis of the armature winding. Frequently it is convenient to split the compensating field winding so that half is connected in the circuit on each side of the load axis of the armature winding, and the diagram is modified as shown in diagram *a*

2. Commutating field windings

If a commutating field winding is used it will be connected in the armature circuit between terminals $A1$-$A2$ or $XA1$-$XA2$

3. Field windings in the load axis

Each terminal of the field windings in the load axis is marked with a single letter and subscript number. Exciting current which flows from the lower to the higher numbered subscript in any one of these windings produces a magnetomotive force and flux along the load axis and a speed voltage in the armature winding of the short-circuit axis of such polarity as to make XA_2 positive and XA_1 negative with clockwise rotation of the armature. The use of the letters and subscripts has additional significance:

S_1S_2, S_3S_4, and so forth, field windings intended for series connection; usually in the armature circuit of either the load axis or the short-circuit axis

F_1F_2, main control shunt field

F_3F_4, reference or counter shunt field

F_5F_6, auxiliary control shunt field

F_7F_8, antihunt shunt field

F_9, F_{10}, F_{11}, F_{12}, and so forth, shunt fields for other purposes than those already noted

4. Field windings in the short-circuit axis

The terminals of the field windings in the short-circuit axis are marked the same as the field windings in the load axis except that the prefix letter X is added. Exciting current which flows from the lower to the higher numbered subscript in any one of these windings produces a magnetomotive force and flux along the short-circuit axis and a speed voltage in the armature winding of the load axis of such polarity as to make A_2 positive and A_1 negative with clockwise rotation of the armature

The use of the letters and subscripts has added significance:

XS_1XS_2, and so forth, field windings intended for series connection; usually in the armature circuit of either the short-circuit axis or the load axis

XF_1XF_2, and so forth, field windings intended for shunt connection

5. Killer windings

A killer winding is sometimes used in special cases to reduce the residual. This may be a special winding or it may be special taps on a winding designed for other purposes. In either event the terminals are marked K_1K_2. Since the exciting current is alternating, the polarity marking is omitted

6. Counterclockwise rotation

The same letters and subscripts are used for both rotations. For counterclockwise rotation the polarities of all field windings and of the armature winding of the load axis remain the same as for clockwise rotation. The polarities of all field windings and the armature winding of the short-circuit axis are reversed. All interconnections of the various windings are the same for both rotations, except that field windings in the load axis which are connected in the circuit of the short-circuit axis, and field windings in the short-circuit axis which are connected in the circuit of the load axis must be reversed when rotation is reversed

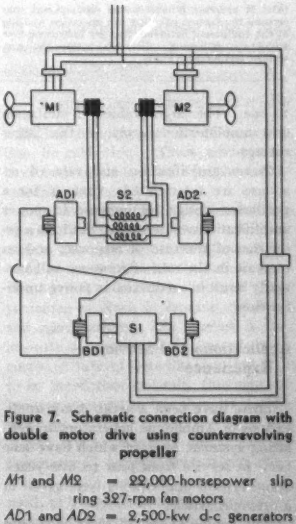


Figure 7. Schematic connection diagram with double motor drive using counterrevolving propeller

M1 and *M2* = 22,000-horsepower slip ring 327-rpm fan motors

AD1 and *AD2* = 2,500-kw d-c generators

BD1 and *BD2* = 3,200-horsepower d-c motors

S2 = 20,000-kva 540-rpm synchronous motor

S1 = 6,000-kva 514-rpm synchronous generator

Guide for Wartime Conductor Temperatures for Power Cables in Service

AEIC SUBCOMMITTEE ON
WARTIME TEMPERATURES FOR CABLE CIRCUITS

Preface: The cable engineering section of the Association of Edison Illuminating Companies recently sponsored a guide particularly for the use of its member power-utility companies in the wartime operation of electric cables of the types as used mainly in underground systems. A large share of the underground cable circuits in this country are operated by the AEIC companies. The details of preparing the guide for the consideration, revision, and approval of the section were handled by a special subcommittee.

The AIEE cable working group sponsored a conference on emergency rating of power cables at the AIEE technical meeting on January 26, 1943, at which nine papers were presented.* Subsequently it seemed desirable to the cable working group to have the AEIC guide also presented for the purpose of giving information to all interested in this country and for stimulating discussion. The information and diversified views in the nine papers were considered in preparing the guide.

This guide is similar in two respects to wartime guides recently prepared by various AIEE committees and subcommittees on various kinds of equipment, namely:

(*a*). It presents principles and assumptions concerning the factors affecting the operation and life of the equipment involved, thereby indicating how to obtain maximum utilization within the prescribed temperature limits.

(*b*). It presents tables of temperatures for occasional emergency use which are above the limits in the AIEE Standards.

Furthermore, this Guide has tables of temperatures for normal operation, that is, day-in and day-out operation, where the temperatures are higher than the limits given in various specifications and standards, including the AIEE Standards. The usage of temperatures such as set forth in the guide for normal operation and for emergency operation will produce sharp increases in rates of deterioration and in rates of failures of cable circuits. Such temperatures are recommended for consideration only as a wartime measure to save critical materials, because their use is otherwise uneconomical as well as damaging to service reliability.

1. Scope

THIS guide has been prepared as an aid in determining reasonable cable operating temperatures for wartime service for both normal and emergency operating conditions. The aim has been to obtain the maximum practical utilization of materials and facilities consistent with maintaining tolerable rates of failure. Tables are presented showing recommended maximum temperatures for representative systems, but the values must be adjusted, in many cases, to take into account the various special conditions that are involved in specific situations. As an aid to the engineer who must make the decision as to the needed adjustments, a large part of the guide is devoted to a discussion of the principles on which the recommendations are based and to suggestions as to the adjustments appropriate for particular cases.

The recommendations cover four types of power cable used mainly in underground systems, namely:

1. Impregnated-paper-insulated lead-covered cable of the solid type.
2. Impregnated-paper-insulated lead-covered cable of the oil-filled type.
3. Varnished-cambric-insulated lead-covered cable.

* A single pamphlet containing all nine papers is available in limited quantity at Institute headquarters at 75 cents a copy.

Paper 43-104, recommended by the AIEE committee on power transmission and distribution for presentation at the AIEE national technical meeting, Cleveland, Ohio, June 21–25, 1943. Manuscript submitted April 21, 1943; made available for printing May 20, 1943.

Personnel of the AEIC subcommittee: Herman Halperin, *chairman*; C. T. Hatcher, and H. W. Collins.

Personnel of the AEIC cable engineering section: W. F. Davidson, *chairman*; G. M. Armbrust, T. J. Brosnan, W. R. Bullard, H. A. Clark, M. T. Crawford, G. E. Dean, R. L. Dodd, F. M. Farmer, C. W. Franklin, T. H. Haines, Herman Halperin, L. I. Komives, C. H. Kraft, S. J. Lisberger, R. E. Morse, H. S. Phelps, F. B. Pinckard, and C. T. Sinclair.

to one. The larger values of excitation and amplification apply to the larger ratings.

Power amplification and rate of response are interrelated; that is, for a particular design an increase in power amplification will normally result in a reduction of the rate of response, and an increase in the rate of response will normally result in a reduction in power amplification.

Applications and Service Experience

There have been a great many applications of Amplidyne generators in regulating systems, some of which have now been in service from four to five years. Some typical applications were given in a previous article.[1]

The service record of these machines and their circuits has been excellent.

Typical of the type of regulation that can be accomplished is the application of Amplidynes to wind tunnel drives. The arrangement of a wind-tunnel-drive apparatus was described in a previous article.[5] Figure 7 shows the schematic connections of the main drive. In these circuits, the following functions were performed with Amplidynes and associated circuits.

1. Variation of field current of constant speed and variable speed d-c machines—*BD*1, *BD*2, *AD*1, and *AD*2 to

(*a*). Controlled acceleration of the variable speed machines from rest to full speed and matching of the line frequency for synchronizing.

(*b*). Controlled acceleration of the main fan motors from rest

(*c*). Maintain fan motor speed within one-fourth of one per cent.

(*d*). Under any condition impose a definite current limit in the circuit between the d-c machines.

2. Variation of field current of variable speed a-c generator S_2 to

(*a*). Match voltages during the synchronizing period.

(*b*). Maintain system power factor during operation of the tunnel.

Owing to the fact that these circuits involve matching the quantity to be regulated against a standard, it is essential that the proper polarities be predetermined and checked before the apparatus is given full power to regulate. In case of error of connections, the system might cause the value being regulated to depart from the standard with increasing voltage rather than bringing about the desired matching.

References

1. Industrial Applications of Amplidyne Generators, D. R. Shoults, M. A. Edwards, F. E. Crever. *General Electric Review*, volume 43, 1940, pages 114–19.

2. The Amplidyne Generator—A Dynamo-electric Amplifier for Power Control, E. F. W. Alexanderson, M. A. Edwards, E. K. Bowman. *General Electric Review*, volume 43, 1940, pages 104–06.

3. Design Characteristics of Amplidyne Generators, A. Fisher. *General Electric Review*, volume 43, 1940, pages 107–13.

4. Steady-State Theory of the Amplidyne Generator, T. D. Graybeal. AIEE Transactions, volume 61, 1942, October section, pages 750–6.

5. Large Adjustable-Speed Wind-Tunnel Drive, C. C. Clymer. AIEE Transactions, volume 61, 1942, March section, pages 156–8.

4. Rubber-insulated cable with and without lead sheath.

This guide is not intended to supersede existing standards and recommended practices for operating temperatures under peacetime conditions of service. Further, it is recognized that if these higher temperatures are used the manufacturer cannot be held responsible under the usual guarantees in standards and specifications for troubles resulting from operation at the increased temperatures.

2. General Principles

Under wartime conditions, the normal balance between many factors that enter into the determination of proper cable operating temperatures is upset. Maintenance of service remains important, but the very high standards of peacetime service may not be justified; economic factors are assigned only small consideration. As a general matter it may be assumed that underground cable systems can operate with failure or trouble rates considerably higher than those reported in the cable operation reports of the Edison Electric Institute without materially affecting the reliability of service to the customers. Some increase in maintenance cost is to be expected, but this is partially offset by the increased use of the investment. Some reduction in life is to be expected; the extent of this is indicated in the assumptions.

Establishment of increased temperatures and increased load ratings under these changed conditions requires a large measure of engineering experience and judgment. However, it is practical to make recommendations as to temperatures for wartime conditions for representative systems and to give sufficient discussion for use in making adjustments in the temperatures as dictated by circumstances peculiar to specific systems.

2.1 Type of System

The recommended temperatures given in Tables I, II, and III apply to representative systems meeting three general conditions. These are:

(*a*). The cable in service was purchased almost entirely under the following standards and specifications: "AEIC Specifications for Impregnated Paper-Insulated, Lead-Covered Cable, Solid Type" (the "Simplified Practice Schedule" issued in 1941 not being included); "AEIC Specifications for Impregnated Paper-Insulated Lead-Covered Cable, Oil-Filled Type"; "AIEE Standard Number 30," issued at various times; "Insulated Power Cable Engineers Association Specifications for Varnished Cambric-Insulated Cables" (the 1939 edition which applies to the recently developed varnished-cambric tapes not being included); the "National Electrical Code," and "ASTM Standard Number 469" for rubber-insulated cable.

(*b*). The system had rates of trouble of the same general order as the national rates of trouble as given in the "Cable Operation Reports" of the Edison Electric Institute. The cable and accessories have no especially bad condition that would lead to a very large increase in troubles with the use of higher temperatures.

(*c*). The power cable systems involved will have reasonably good maintenance, which includes periodic inspections in manholes and repairs when found necessary.

2.2 Temperatures—Definitions

2.21 The temperatures referred to are those at the hottest portion of the cable in a given line or circuit. Where these limiting temperatures exist in only a small portion of the line, attention should, obviously, be given to a determination of the extent to which corrective measures may be justified. (Section 3.8)

2.22 The "normal" temperatures are the maximum copper temperatures that may be reached in regular daily operation during wartime when all of the lines or circuits for a given supply are in service. Where, for example, the daily load cycles for the first five days of the week are practically the same and then the load drops considerably over the week end, then the suggested maximum allowable normal temperature would apply to the conditions that produced the maximum temperature during the week.

2.23 The "emergency" temperatures apply to special operation occurring not more than four periods in any 12 consecutive months for all of the types of cable except the oil-filled type, for which the limiting number of periods is two in any 12 consecutive months. The duration of the special operation is assumed to be a continuous period of time of 24 hours or less for all the types of cable except for the oil-filled type, for which it is assumed that each period is 60 hours or less.

2.24 It is assumed that, both in normal and in emergency operation, the cable is at approximately the maximum temperatures for a few hours or more in each daily lead cycle, which is practically the condition when lines or circuits have their daily heavy-load periods for eight or twelve hours or more.

2.3 Recommended Temperatures

2.31 For impregnated-paper-insulated cables of the solid type the temperatures for normal operation are from 4 to 15 degrees and for emergency operation from 10 to 40 degrees centigrade higher than the temperature limits given in the AEIC Specifications and the AIEE Standards. Lower temperatures are shown in Table I for shielded three-conductor cables than for single-conductor cables, because the maximum temperatures for three-conductor shielded cables are more limited by the effect of cable movement upon the sheath life than by deterioration of the insulation.

2.32 For oil-filled cables the temperatures for normal operation are ten degrees centigrade above the limits given in the AEIC Specifications except for voltages below 26 kv where the increases are smaller, and the proposed emergency temperatures are from 25 to 30 degrees centigrade above the AEIC limits for emergency operation except for voltages below 26 kv.

2.33 For varnished-cambric cables the proposed normal temperatures are from 8 to 14 degrees centigrade above the limits given in AIEE Standard 30, and the proposed emergency temperatures are from 23 to 31 degrees centigrade above those limits.

2.34 For rubber-insulated cables except those with ozone-resistant compounds, the proposed normal temperatures are from 5 to 20 degrees above the limits given in the 1940 National Electrical Code and the proposed emergency temperatures are from 15 to 40 degrees centigrade above those limits. No standard limits are available for ozone-resistant compounds, but general values from manufacturers have been about the same as given in the table.

2.4 Assumed Influence on Cable Life

Higher temperatures result in reduction in cable life. Three assumptions have been made as a basis for the recommendations.

2.41 It is assumed that the wartime "normal" temperatures will at least double the rate of deterioration of the cable as compared with the rate for previous practices based on "normal" temperatures as given in existing standards and specifications. The increase in failure rate will be one indication of an increase in rate of deterioration, but it is to be noted that generally this may not become apparent in less than six months or a year.

2.42 It is assumed that wartime "emergency" temperatures would cause a loss of life, for each period they are used, of less than one per cent of the expected life of the cable and accessories when they were new, and that they would cause no immediate failures.

2.43 The increases in the rate of deterioration for normal operation and in

the loss of life of one per cent or less for emergency operation are meant to apply to either the insulation or the sheath as the case may be. It should be recognized that in many cases cable systems have operated at temperatures considerably below the limits given in national standards. In such cases the use of the recommended temperatures in this guide and their accompanying increased temperature ranges may cause increases of 200 or 400 per cent or even more in the rates of deterioration over the rates that previously obtained. The suggested maximum allowable temperatures for wartime operation are based on a large amount of experimental data and operating experience. "Special Considerations" discusses this at some length for a number of cases, while there is more extensive discussion in several papers listed in the bibliography.

3. Special Considerations

3.1 Influence of Operating Voltage

Temperatures are given in the tables for various nominal operating voltages and were determined by the formulas shown. For other nominal operating voltages, the suggested allowable temperatures can be determined by interpolation from the temperatures in the tables or by the use of the formulas.

3.2 Lead Sheath

3.21 For normal temperatures which apply to day-in and day-out operation, one of the main factors affecting the determination of the temperature for lead-sheathed cable is the effect of daily movement of the cable in the manhole incidental to cyclic loading. Such movements may lead to cracking through the sheath before the insulation becomes unserviceable. The temperatures given in the tables are based on the assumption that the daily load varies considerably through each 24-hour period and there is one general movement of the cable in and out of the duct in each 24 hours. If the loading is such as to have two general cycles of movement back and forth, then the temperatures should be reduced in order to avoid considerable cracking through the sheaths in the manholes. On the other hand, if the loading is fairly steady through each 24-hour period, then this factor may permit the use of higher normal temperatures.

3.22 In connection with sheath cracking in manholes incidental to daily cyclic loading, another factor is the training of the cable in the manhole as well as the size of manhole. Where the offset between the center line of the duct and the center line of the line is small, or the bending radii of the cable are small, or the total length between joint wipe and duct mouth is small, then the effect of a given movement of the cable at the duct mouth in causing sheath cracks is increased. Where these characteristics are particularly below what may be considered good practice, then there should be a corresponding reduction made in the allowable temperatures, especially where the daily temperature ranges are large.

3.23 The amount of cable movement at the duct mouth is affected by the length of cable between manholes, within limits. For short lengths of cable, such as 100 or 200 feet, the allowable copper temperatures might be set somewhat higher than given in the tables as far as considerations of the lead sheath are concerned.

3.24 For a given length of cable and temperature range, the amount of movement at the duct mouth is somewhat proportional to the ratio of the total cross section of the copper conductors in the cable to the weight of the cable. For a cable having relatively small conductors, the temperatures might be set at somewhat higher values than given in the tables.

3.25 The strain of the sheath in the manhole incidental to a given movement at the duct mouth is somewhat proportional to the diameter of the cable. Where the cable diameters are considerably more than about one and one half or two inches for low-voltage cables or about two or three inches for high-voltage cables, then the maximum temperatures for normal daily loading might well be less than given in the tables. Where the cable diameters are particularly small, then higher temperatures than given in the tables may be permissible for normal operation.

3.26 Impregnated - paper - insulated cable installed vertically or on steep slopes may be subject to excessive sheath expansion from the internal hydrostatic pressure. The expansion of the lead sheath is accelerated by the rise in temperature of the sheath. For practical purposes it is well to assume that the rate of creep doubles for an increase of about 17 degrees centigrade.

3.27 Where solid-type cables are operated with reservoirs under positive pressure connected to joints, consideration must be given when increasing operating temperatures to the possibility of increased sheath expansion and an increased rate of sheath bursting. Reduction of reservoir pressure may be considered as a compensating measure.

3.28 In locations where corrosion is a problem, increased sheath temperatures may increase the rate of chemical reaction and failures resulting from corrosion.

3.3 Conduit

3.31 Another important factor related to the use of higher temperatures for normal operation is the effect of the accompanying increase in conduit temperatures. In some cases the use of the increased temperatures will result in drying out the conduit and surrounding soil with a resultant increase in the heating constant, that is, the thermal resistance between the cable and base ambient, which is unheated earth some distance from the conduit for underground installations. As regards temperatures for emergency operation, the main point on the heating of the conduit is the fact that the tem-

Table I. Maximum Conductor Temperatures for Impregnated Paper-Insulated Lead-Covered Cable for Wartime

Caution: Values in tables are not to be used without full consideration of limitations discussed in text

Nominal Operating Voltage—Kilovolts (Phase-to-Phase)	Maximum Conductor Temperature—Degrees Centigrade: Normal Operation	Emergency Operation
Single-Conductor Cable, Solid Type		
0–1	100	125
4	98	121
13	92	113
22	87	105
27	84	100
33	81	95
44	75	84
66	64	70
Three-Conductor Shielded Cable, Solid Type		
13	87	108
22	82	100
27	79	95
33	76	90
Multiple-Conductor Belted Cable, Solid Type		
0–1	98	125
4	94	115
13	85	104
22	76	94
27	71	88
33	65	80
Oil-Filled Type of Cable		
35 and less	85	115
66	85	110
132	80	105

Rules for establishing temperatures shown were as follows:

Type of Cable	Normal Operation	Emergency Operation
Single-conductor, solid	$100 - E$ (100 degrees centigrade for 0–1 kv and minimum of 64 degrees centigrade)	$125 - 1.6E$ (125 degrees centigrade for 0–1 kv and minimum of 70 degrees centigrade)
Three-conductor shielded, solid	$95 - E$	$120 - 1.6E$
Multiple-conductor, belted, solid	$98 - E$ (98 degrees centigrade for 0–1 kv)	$120 - 1.2E$ (125 degrees centigrade for 0–1 kv)

E is kilovolts between phase and ground for single-conductor and three-conductor shielded cables and between phases for multiple-conductor belted cables.

perature of the conduit may go up a few degrees for each 24 hours of emergency loading.

3.32 In all calculations as to carrying capacities for a given installation or installations of cable circuits, certain assumptions are made as to the effect of the heating of the cables in raising the temperature of the conduit or air surrounding the cable. If the assumptions are based on factual data obtained by surveys of the conduits and the installations are further followed up by surveys after the circuits are in operation, then the copper temperatures can be calculated with a good degree of accuracy. In such cases the load ratings may be determined without making especially liberal allowances for the temperature rise of the duct or other ambient over the base ambient. If surveys of conduits are made where the cables are operating at relatively high temperatures, then the load ratings can be made somewhat higher than would be the case if no surveys are made. If no factual data are available on the heating characteristics of the medium in which the cable is to be installed and no surveys are to be made, then the temperature that is used in calculating the load ratings might well be five or ten degrees centigrade less than given in the tables. On the other hand, where complete data are available and field surveys are continually made, it may be feasible to use temperatures of a few degrees up to ten degrees centigrade above the limits given in the tables for paper-insulated cables, the larger increases applying to the lower-voltage cables.

3.33 The total carrying capacity of all the cables in a conduit, expressed in kilovolt-amperes, may be increased in some cases by relocating some of the relatively lower-voltage cables into other conduits. Although the increase in current-carrying capacity for the higher-voltage cables might be small, the increase in kilovolt-amperes might be rather large.

3.4 Insulation

3.41 For, particularly, impregnated-paper-insulated cable made prior to 1920 and having high dielectric losses, and for varnished-cambric-insulated cable used at about nine kv and higher, the existence of large variations in dielectric loss, especially at the higher temperatures, should be recognized in calculating the carrying capacities. Where the information on dielectric losses throughout the expected temperature range of operation for a particular kind of cable is not available, then reasonably large allowances should be made for the dielectric losses or the temperature limits used should be somewhat less than given in the tables for both normal operation and emergency operation. Special attention should be given to the possibility of failures resulting from thermal instability for old cables with high dielectric losses.

3.42 Another effect of the temperature range is in the production of ionization in the solid-type paper-insulated cable. For old belted-type cable such as made in the period of 1920–30 with somewhat less insulation than used prior to 1920, the effect of ionization in normal operation may be considerable in some instances. If the operating experiences have indicated this to be the case, a small reduction below the temperatures given in the table for normal operation should be made, and a somewhat larger reduction should be made in temperatures for emergency operation.

3.43 Cable that has operated at temperatures corresponding to voltages much below its rated voltage may become unfit so far as the insulation is concerned to operate subsequently at rated voltage.

3.44 The insulation of recently made paper-insulated cable of the solid type can withstand somewhat higher temperatures for emergency operation than given in the table.

3.45 Varnished - cambric - insulated cable made in the past few years can withstand temperatures roughly five degrees centigrade higher than given in the table for both normal and emergency operation.

3.46 It should be noted that the resistance to effects of heat by rubber compounds of a given class has been found to vary considerably. If test or operating data are available for a given installation, the data may be used to modify the temperatures in the guide somewhat up or down.

3.47 Deterioration of rubber is greatly accelerated by oxidation. As a consequence, higher permissible temperatures are shown in Table III for lead-sheathed cable than for cables without lead sheath, except for ozone-resistant compounds, where the maximum temperatures are limited by softening of the insulation. Where the ends of lead-sheathed cables are of such construction as to allow air to be more or less in free contact with the rubber insulation, then, excepting ozone-resistant compounds, somewhat lower temperatures than given in the table may be advisable.

3.5 Accessories

3.51 In some instances the loading of the cables in emergencies to the temperatures given in the tables will result in movements at the duct mouth of one and one half or two and one half inches or even more. Training of the cable in the manhole should be such as to permit these large movements without buckling of the cable or jamming of the joint against the manhole wall or other joints or undue mechanical strains on connections to the joints to cause serious damage. If this is not feasible, then lower temperatures than given in the tables for emergency operation are suggested.

3.52 In some cases joints and potheads may develop troubles if operated at the emergency conductor temperatures given in the tables. This applies particularly to the higher-voltage cables. In general, however, the accessories on an underground system operate with ambients 15 or 25 degrees centigrade below the maximum duct temperature along the circuit at the time of emergency operation, and so the possibility of trouble with the accessories in such instances is thereby reduced or eliminated. The point, however, is of significance where the cable and accessories are all exposed to the same ambient, as might be the case with an open installation of a circuit in a generating station.

3.53 Where joints are filled with viscous or hard compound, increased tempera-

Table II. Maximum Conductor Temperatures for Varnished-Cambric-Insulated Lead-Covered Cable for Wartime

Caution: Values in table are not to be used without full consideration of limitations discussed in text

Nominal Operating Voltage—Kilovolts (Phase-to-Phase)	Maximum Conductor Temperatures—Degrees Centigrade: Normal Operation	Emergency Operation
Three-Conductor Shielded and Single-Conductor Cable		
0–1	88	105
4	85	102
13	77	94
22	70	86
27	70	82
Multiple-Conductor Nonshielded Cable		
0–1	88	105
4	82	99
13	70	85

Rules for establishing temperatures shown were as follows:

Normal Operation	Emergency Operation
$88 - 1.5\,E$ (88 degrees centigrade for 0–1 kv and minimum of 70 degrees centigrade)	$105 - 1.5\,E$ (105 degrees centigrade for 0–1 kv)

E is kilovolts between phase and ground for single-conductor and three-conductor shielded cables and between phases for multiple-conductor nonshielded cables.

Table III. Maximum Conductor Temperatures for Rubber-Insulated Cable in Wartime

Caution: Values in table are not to be used without full consideration of limitations discussed in text

Nominal Operating Voltage—Kilovolts	Maximum Conductor Temperature—Degrees Centigrade			
	Normal Operation		Emergency Operation	
	No Lead Sheath	Lead-Sheathed	No Lead Sheath	Lead-Sheathed
Code and Intermediate Compounds				
0–1	60**	70*	70	90*
30 Per Cent Class *AO*, Performance, and Other Similar Compounds				
0–7.5	65	75*	75	95*
Ozone-Resistant Compounds (Oil Base)				
0–7.5	75	75	85	85
7.6–15	70	70	80	80

* Terminal ends of cable assumed to be sealed against entrance of air.

** These temperatures are based on the 1940 National Electrical Code, which gave 60 degrees centigrade for code rubber together with Interim Revision Number 41 dated February 26, 1942, which permitted the use of the higher current ratings given in the previous editions of the code.

tures may cause trouble because of bulging of the casing or because of repeated bulging and collapsing of the casing.

3.54 Reservoirs may be subjected to volume expansion to beyond their limits when cables are operated at some of the higher temperatures given for oil-filled cables, and for those installations of solid-type cable having oil-filled reservoirs connected to the oil-filled joints. Therefore, special provisions should be made to take care of extra expansion of the impregnating compound or oil of the cable where the present reservoirs are inadequate.

3.55 Consideration must be given for oil-filled cable installations to the fact that dropping of heavier loads corresponding to higher temperature limits will result in hydrostatic pressure drops in the cable system greater than contemplated in the original design of the oil supply system. Provision must be made to prevent pressures below atmospheric forming at any point of the line under these conditions.

3.6 Load Cycles

As indicated under "General Principles" the recommended temperatures are based on the assumption that the cable may operate at about these temperatures for a few hours or more in a day. The heavy portion of the load of a given day may be of such short duration that no stable temperature conditions are attained and the maximum temperature is reached only momentarily. In such an event, if the temperature before the time of heavy load is considerably below the permissible temperature in the tables, then the maximum temperature could be five or ten degrees centigrade above the value in the tables, the higher temperatures applying to the lower voltages. This statement applies to temperatures during normal or emergency operation as the case may be.

3.7 Inspection

It is recommended that when lines or circuits are operated at temperatures such as given in the tables, the cable systems be given increased inspection. In the case of emergency operation the inspection should be made with little delay.

3.8 Special Measures

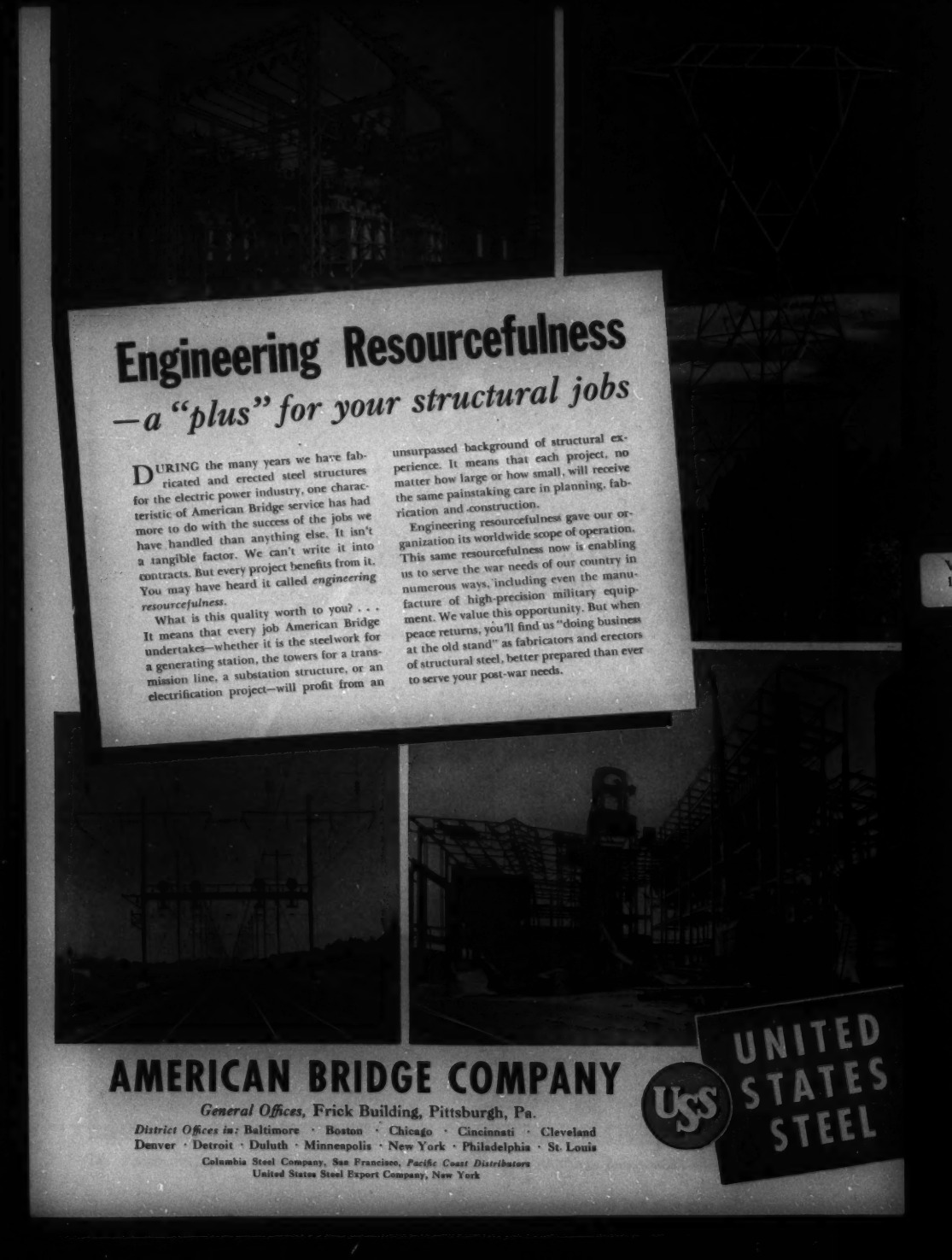
As previously indicated, the utilization of lines and circuits already in service can be increased within the allowable temperature limits in this guide through certain practices and arrangements, some of which are listed below:

1. Temperature surveys.
2. Increased inspection and maintenance program.
3. Changing solid bonding to special bonding for single-conductor cables to eliminate sheath losses.
4. Forced cooling by water or air during special temperature peaks at especially hot spots.
5. Elimination of local thermal bottlenecks by
   (*a*). Use of larger conductors.
   (*b*). Change of soil around conduit, as by replacing cinder fill.
   (*c*). Relocating sources of external heat.
   (*d*). Spreading of cables in crowded location.
6. Relocation of one or two cables to permit an increase in kilovolt-ampere loading of the remaining cables above the load carried on the removed cables.
7. Improvements in training of cable in manholes.

References

1. Pyrochemical Behavior of Cellulose Insulation, F. M. Clark. AIEE Transactions, volume 54, 1935, October section, pages 1088–94.
2. Temperature Limits Set by Oil and Cellulose Insulation, C. F. Hill. AIEE Transactions, volume 58, 1939, September section, pages 484–7.
3. Factors Influencing the Mechanical Strength of Cellulose Insulation, F. M. Clark. AIEE Transactions, volume 60, 1941, July section, pages 778–83.
4. Load Ratings of Cable, Herman Halperin. AIEE Transactions, volume 58, 1939, October section, pages 535–53.
5. Maximum Safe Operating Temperature for 15-Kv Paper-Insulated Cables, C. W. Franklin, E. R. Thomas. AIEE Transactions, volume 58, 1939, October section, pages 556–60.
6. Temperature Aging Characteristics of Class A Insulation, J. J. Smith, J. A. Scott. AIEE Transactions, volume 58, 1939, September section, pages 435–42.
7. Load Ratings of Cable—II, Herman Halperin. AIEE Transactions, volume 61, 1942, pages 930–42.
8. Results of Emergency Overload Tests on 24-Kv 3-Conductor Paper and Lead Cable, G. B. McCabe, J. Sticher. *Edison Electric Institute Bulletin*, November–December, 1942, page 405.
9. Calculations of Electrical Problems of Underground Cables, D. M. Simmons. *Electric Journal*, May to November, 1932.

The careful investor judges a security by the history of its performance.
KERITE
in over three-quarters of a century of continuous production, has established a record of performance that is unequalled in the history of insulated wires and cables.
Kerite is a seasoned security.
DAYS
KERITE
DAYS
KERITE



Engineering Resourcefulness

—a "plus" for your structural jobs

DURING the many years we have fabricated and erected steel structures for the electric power industry, one characteristic of American Bridge service has had more to do with the success of the jobs we have handled than anything else. It isn't a tangible factor. We can't write it into contracts. But every project benefits from it. You may have heard it called *engineering resourcefulness*.

What is this quality worth to you? . . . It means that every job American Bridge undertakes—whether it is the steelwork for a generating station, the towers for a transmission line, a substation structure, or an electrification project—will profit from an unsurpassed background of structural experience. It means that each project, no matter how large or how small, will receive the same painstaking care in planning, fabrication and construction.

Engineering resourcefulness gave our organization its worldwide scope of operation. This same resourcefulness now is enabling us to serve the war needs of our country in numerous ways, including even the manufacture of high-precision military equipment. We value this opportunity. But when peace returns, you'll find us "doing business at the old stand" as fabricators and erectors of structural steel, better prepared than ever to serve your post-war needs.

AMERICAN BRIDGE COMPANY

General Offices, Frick Building, Pittsburgh, Pa.

District Offices in: Baltimore · Boston · Chicago · Cincinnati · Cleveland
Denver · Detroit · Duluth · Minneapolis · New York · Philadelphia · St. Louis

Columbia Steel Company, San Francisco, *Pacific Coast Distributors*
United States Steel Export Company, New York

USS UNITED STATES STEEL

YOU CAN BREAK LOAD WITH THIS SWITCH

Wall Mounting Type

and Get Short-Circuit Protection with a Fuse Combination

● Manual switching of high voltage circuits—and reliable short-circuit protection are provided in one unit assembly,—in one cabinet, by the Load-Interrupter Disconnect and Fuse Equipment designed and pioneered by S&C.

The Load-Interrupter Switch is capable of interrupting up to 400 amperes at 15,000 volts without drawing an arc across the main switch contacts. The Heavy Duty Fuses have short-circuit interrupting ratings of:—20,000 r. m. s. amperes at 13,200 volts; 25,000 r. m. s. amperes at 6600 volts; 30,000 r. m. s. amperes at 2300/4000 volts.

For many services where all the functions of circuit-breakers are not essential, this load-switching and fuse combination assembly has found wide acceptance during the past few years, effecting savings in initial installation and maintenance costs, and conserving critical metals.

These assemblies are installed at substations, main and branch feeders, and employed as throw-over devices from two alternate feeders. Consult the nearest S&C office for further details of this equipment and its many applications,—or write today for Bulletins 202-A and 763.

SCHWEITZER & CONRAD, Inc.
4435 Ravenswood Avenue CHICAGO, ILLINOIS

WHAT ARE YOUR D. C. CONTROL REQUIREMENTS?

Whatever your D. C. control problem, a Square D Field Engineer will welcome an opportunity to help you. His background of practical experience and Square D's *three complete lines* of D. C. control most likely will provide an effective solution.

HEAVY DUTY CONTROL up to 600 volts and 300 amperes is furnished for machine tools and general industrial applications. Available components include contactors and timing relays, control relays, field relays, overload relays, and Edgerest resistors. From these heavy duty units, marine control is also assembled to meet AIEE marine specifications.

ELECTRIC TRUCK CONTROL devices are built for voltages up to 115. Contactors, timers and relays are front connected for mounting on steel panels.

LOW VOLTAGE D. C. control devices have a wide range of applications on aircraft, tanks, boats, trucks and other portable or mobile equipment. Contactors, relays, push buttons, manual switches and circuit breakers are available up to 24 volts.

ELECTRICAL EQUIPMENT • KOLLSMAN AIRCRAFT INSTRUMENTS

SQUARE D COMPANY

DETROIT • MILWAUKEE • LOS ANGELES

CONTROL CENTERS

Fabricated by KIRK & BLUM

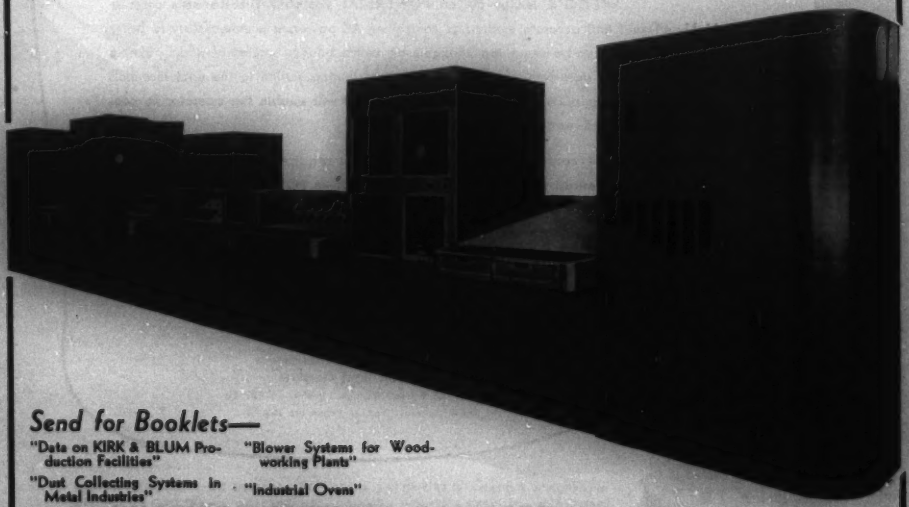
The illustration below is a series of control panels and desks for an airplane motor test room. This entire assembly is an excellent example of one of the various sheet metal products fabricated by Kirk & Blum in strict adherence to customer's design and specifications.

With a background of specialized experience of more than thirty-six years, fabricating sheet metal products for various industries, we can, with equal skill and dexterity, fabricate your special products. Our extensive modern plant facilities and a corps of skilled workmen are further assurance that your work will be completed with speed and economy.

Consult Kirk & Blum Engineers. They will analyze your problems and make recommendations to solve them to your decided advantage.

ACCURATE SHEET STEEL FABRICATION—CAPACITY 3/8 INCH and LIGHTER

SEND US YOUR BLUE PRINTS for PROMPT QUOTATIONS



Send for Booklets—

"Data on KIRK & BLUM Production Facilities"

"Dust Collecting Systems in Metal Industries"

"Fan Systems for Various Industries"

"Blower Systems for Woodworking Plants"

"Industrial Ovens"

"Cooling Systems for the Glass Industry"

THE KIRK & BLUM MANUFACTURING CO.

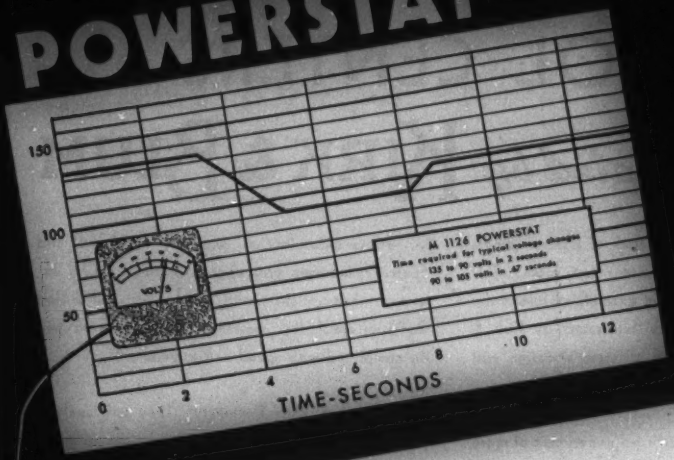
AN ORGANIZATION OF ENGINEERS AND MECHANICS

2955 SPRING GROVE AVE. CINCINNATI, OHIO

Certainly,

POWERSTAT

variable voltage transformers



for REMOTE CONTROL

SECO'S Motor-Driven POWERSTAT Variable Transformers offer a highly efficient and accurate method of controlling AC power. It is unnecessary to bring heavy cable to cumbersome tap changers on switch boards or control desks. Simple wiring from your automatic control device or push button station to the pilot terminals of a Motor-Driven POWERSTAT Variable Transformer will enable the operator to control kilowatts of power safely and smoothly.

Where a self-contained piece of apparatus is required for rapidly controlling voltage to any desired value — investigate Motor-Driven POWERSTAT Variable Transformers. This equipment is used in radio transmitters, vacuum tube manufacture, electrical testing, induction heating, electric furnace temperature control, automatic voltage regulators and other applications where an efficient high quality control is required.

Standard types are available in sizes up to 75 KVA for 115, 230 or 440 volt operation on single or polyphase circuits.

FOR FURTHER INFORMATION
SEND FOR THESE BULLETINS
POWERSTAT Variable Voltage Transformers 149 EE
SECO Automatic Voltage Regulators 163 EE

SUPERIOR ELECTRIC COMPANY
72 LAUREL STREET, BRISTOL, CONNECTICUT

SUPERIOR *Electric Company*

Dunco "Memory" Types

THE RELAYS THAT NEVER FORGET

Struthers-Dunn Mechanical Latch-in, Electrical-Reset Relays have fool-proof memories. They indicate what operations have been made on your equipment. They guard against mistakes. The contacts "remember" unfailingly which coil was last energized—*by remaining in position until they are released by energizing the other coil.*

Hundreds of jobs throughout industry are being performed better, more efficiently because these Struthers-Dunn Memory Relays permit of no forgetting. They are made in both the large (Series 5) and the "midget" (Series 51) sizes as well as aircraft types, and with practically any contact or mounting arrangement. You'll find these Relays described in detail on Pages 14F, 15F, and 16F of the Dunco Catalog and Relay Data Book (see below).

DISTRICT ENGINEERING OFFICES: ATLANTA • BALTIMORE • BOSTON • BUFFALO
CHICAGO • CINCINNATI • CLEVELAND • DALLAS • DENVER • DETROIT • HARTFORD
INDIANAPOLIS • LOS ANGELES • MINNEAPOLIS • MONTREAL • NEW YORK • PITTSBURGH
ST. LOUIS • SAN FRANCISCO • SEATTLE • SYRACUSE • TORONTO • WASHINGTON

WRITE FOR CATALOG!

STRUTHERS-DUNN, Inc.

1321 ARCH STREET, PHILADELPHIA, PA.

PERMANENT MAGNETS MAY DO IT BETTER

Are You, Too, Planning For "*The Age of Electronics?*"

WITH many electronic developments proving successful on the battle-fronts, it's only natural for America's scientists and engineers—busy as they are—to sense the importance of peace-time applications from the miracles they have wrought. And the postwar results of their thinking will create "The Age of Electronics."

Whether you are manufacturing war matériel or planning peacetime products, have you considered incorporating the principle of the *permanent magnet?* Permanent magnets of our design and manufacture are used in many of the war's outstanding electronic developments and in countless other important devices—increasing their uses and improving their functions. 33 years of specializing in this *one* field has enabled us to make valuable engineering contributions. Very likely we can help *you*, too.

Though our plant (the nation's largest specializing in the making of permanent magnets) is devoted to war orders, our engineers will be glad to consult with you and give your problems the benefit of their unusual experience. Write for the address of our office nearest you and a copy of our 30-page "Permanent Magnet Manual."

Back the attack with an EXTRA Bond—and help increase production!

The
INDIANA STEEL PRODUCTS
Company

★ SPECIALISTS IN PERMANENT MAGNETS SINCE 1910 ★

6 NORTH MICHIGAN AVENUE • CHICAGO, ILLINOIS

1. Mounting enemy plane crack-ups result from . . .

2. . . . the superior equipment and shooting ability of American pilots.

3. One equipment requirement is an ample supply of strong, well-made ammunition belts to feed the bullets through the guns.

4. To meet this demand, looms for weaving the belts were speeded up and the motors operating the looms were frequently overloaded.

What one man and 40 loom-motors did about it

To quote from the Plant Superintendent's letter:

"Early in 1942, we installed 40 new narrow-fabric looms, individually driven by glass-wound motors . . .

"Since the installation of the looms, we have overloaded them to step up production, but this has had no adverse effect on the motors whatever. We are very pleased with their performance, and they certainly are neat and compact. Believe me, all motors purchased for my division will be glass-wound motors in the future." (1)

The glass in these motors is Fiberglas* Electrical Insulation.

This insulation can withstand frequent overloading . . . just one of the reasons why design engineers, plant superintendents, and maintenance men are using increasing amounts of Fiberglas for important wartime applications.

They are using the low space factor of Fiberglas to make smaller, lighter, more compact equipment. They are skilfully combining it with suitable impregnants to take advantage of its great resistance to moisture, acids, corrosive vapors, and other causes of insulation breakdowns.

Used by Services

The Army and Navy have also recognized these qualities of Fiberglas and are finding increasing uses for it in the important fighting equipment—from battle ships to airplanes.

Since these vital Army and Navy requirements come first, even the constantly increasing production of Fiberglas electrical insulation is sometimes strained. But there is still enough to take care of those jobs where Fiberglas is the only suitable material.

Ask your electrical distributor for technical data on Fiberglas and its availability for your war use. Or write: *Owens-Corning Fiberglas Corporation, Toledo, Ohio. In Canada, Fiberglas Canada, Ltd., Oshawa, Ontario.*

FIBERGLAS
T. M. Reg. U.S. Pat. Off.

ELECTRICAL INSULATIONS

(1) Name on request.

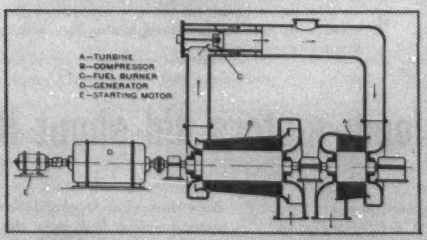
File....but

NEW IDEAS IN POWER AND ELECTRICAL EQUIPMENT ARE TAKING AVAILABLE UNDER HIGH PRIORITIES....ALL BELONG IN THE

☛ Power plant of the future probably will be built around gas turbines... operating at efficiencies equal to or better than diesels but with the low maintenance and simple lubrication of steam turbines. Building space per unit output will be lowest of any prime mover and no water will be required.

Present signs: already 19 Allis-Chalmers gas turbines and compressor units are employed in refining high-octane gasoline.

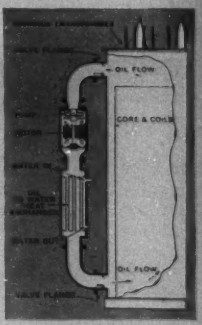
Operating sequence: 1) starting motor slowly rotates unit, building up air pressure, 2) fuel burner is ignited and hot gas enters turbine, 3) turbine takes load, drives compressor and generator, starting motor is disconnected.



OPERATING DIAGRAM OF MODERN COMBUSTION TURBINE

☛ Just moving oil faster in special transformer radiators — cools it enough so that designers need less copper and steel in transformer cores and coils. Allis-Chalmers "Electro-Cooler" does just that—but what's more it's done so simply that it makes forced oil cooling practical. That's the magic word—PRACTICAL!

So now that water-cooling coils are banned by WPB—and electric furnace transformers must be built without them—the "Electro-Cooler" with an oil-to-water heat exchanger replaces them. Allis-Chalmers transformer engineers save copper tubing—give steel makers a substitute for the water-cooled furnace transformer.



OIL-TO-WATER "ELECTRO-COOLER"

Investigate the widening applications of the "Electro-Cooler"—a unit composed of a heat exchanger and a "pump-in-a-pipe." Motor and pump are both immersed and lubricated by cooling oil.

☛ In the heart of a mercury arc rectifier, power-carrying electrons await the moment when a flash of bluish lightning will carry them from the anode to the cathode. There's one anode in each tank of a 6-tank Allis-Chalmers "Excitron" rectifier. Every 360th of a second, in sequence, bluish arcs flash in these tanks. What is the wizardry that times these arcs?

Excitrons are built to "fire when ready"—a procedure made possible by continuous excitation!

At the precise moment that a-c voltage on the anode equals the internal resistance of the mercury vapor gap—the bluish arc "train" leaves for the cathode.

ALLIS

don't forget

SHAPE FAST AT ALLIS-CHALMERS TODAY. SOME ARE ALREADY BACK OF EVERY LONG-RANGE PLANNER'S HEAD. HERE ARE A FEW:

Six pilot arcs burning steadily do the trick—they're always ready to start the "trains" on the 360th of the second. Herein lies the simplicity and stability of the Allis-Chalmers "Excitron."

High priority wall surrounds "Excitron" today, prevents all but most essential uses.

But plan to use it postwar. Higher efficiency of "Excitron" suggests profitable replacement of thousands of motor generator sets and synchronous converters.

☛ Keep your eye on stronger trend toward air blast circuit breakers. Past year has seen Allis-Chalmers air-blast installations more than doubled.

Think of air-blast breakers in terms of protection and maintenance savings. Arcing times, less than 1/2 cycle throughout operating range, mean amazing contact life.

1,000,000 KVA AIR BLAST

Here's how it works in brief: small contact piston pulls back from orifice, high pressure dry air rushing into hole. Arc rushes through, too . . . stretches out and vanishes—at split-cycle speed.

Reliability? Air brake systems of heavy trains are no safer.

OSCILLOGRAM OF AIR BLAST INTERRUPTION

☛ Biggest graphite "pencils" in the world write the flaming story of armor in the electric arc furnaces of Uncle Sam. Formerly these pencil-like electrodes were misguided by erratic up and down movements—calculated to keep pace with the melting charge. But at 3000 deg. F—over-travel and under-travel just burned them up and caused inefficient melting.

With a new sensitive, wide-range control generator called the "Regulex" exciter — Allis-Chalmers engineers are keeping furnace arcs constant, enabling extra "heats" per day, conserving graphite electrodes. Steel men are happy now!

Basic fact is that amplifying characteristics of "Regulex" exciter parallel in many respects those of the electronic tube—with the important exception that it has d-c machine life and ruggedness.

Look for other important new developments in electrical and power equipment from Allis-Chalmers. Maybe we can help you — maybe you can help us. ALLIS-CHALMERS, MILWAUKEE, WIS. A1612

-CHALMERS

ALWAYS
READY FOR USE

THE NEW "MEGGER"* INSULATION TESTER . . .

a worthy addition to the famous "MEGGER" family!

MADE IN U.S.A.

- HAND-CRANKED GENERATOR
- DIRECT-READING OHMMETER
- SIMPLE
- RUGGED
- RELIABLE

*Trade Mark Reg. U. S. Pat. Off.

With our Philadelphia factory now in full production, your needs for "Megger" Insulation Testers can soon be met.

Our new U. S. models are of the same general design and are similar in every way to our well-known "Meg" and "Super-Meg" Insulation Testers, except that they are housed in plastic molded cases instead of aluminum. All internal parts are made to the same proven design and specifications as the "Meg" instruments,—without compromise or substitution of materials. The cases are of high impact strength plastic,—one of the strongest, toughest molding materials available.

The entire instrument is built in our own plant by men and women who know how to make fine instruments. Our production is independent of the products of other instrument manufacturers.

We are fully confident that you will find these new Insulation Testers worthy members of the famous "Megger" family, and we invite your orders for them. At present we are offering ranges up to 100 and 1000 megohms with 500-volt generators. We continue to supply various other types and ratings of "Megger" instruments as formerly. Write for new descriptive Bulletin 1735-EE.

JAMES G. BIDDLE CO. · 1211-13 ARCH STREET · PHILADELPHIA 7, PENNA.

MODEL	-hp- RESISTANCE-TUNED AUDIO OSCILLATORS		
200A	35-35,000 cps Output 1 watt into 500 ohms	Cabinet mounting	$ 95.00
200B	20-20,000 cps Output 1 watt into 500 ohms	Cabinet mounting	95.00
200C	20-200,000 cps Output 10 volts into 1000 ohms	Cabinet mounting	135.00
200D	7-70,000 cps Output 10 volts into 1000 ohms	Cabinet mounting	150.00
202D	2-70,000 cps		250.00

no zero setting

hp Resistance-tuned AUDIO OSCILLATOR

Just three dials on this audio oscillator: range selector, output voltage control and the main frequency dial. This simplicity of design makes for utmost speed in operation and yet there is no sacrifice in accuracy. Of outstanding importance is the fact that no zero setting is required even during the first few minutes of operation. The frequency stability can be depended upon over long periods as well as the accuracy of the calibrations which are for direct reading.

★ Remember these outstanding features: Low Distortion, Logrithmic scale, constant output, no zero setting, simplicity of operation and small physical size which increases their usefulness in all applications. Get complete information about these *-hp-* Resistance-Tuned Audio Oscillators today. A 24-page catalog which gives much valuable information about electronic measuring devices as well as complete technical data on many *-hp-* instruments will be sent you free of charge.

HEWLETT-PACKARD COMPANY

682

P. O. BOX 1135-P—STATION A, PALO ALTO, CALIFORNIA

G&W FACTORY TESTING SAVES YOU TROUBLE

Factory testing of products is routine with G & W.

- Cable boxes, oil switches and cutouts must be air-tight, water-tight and oil-tight. To make sure that these devices are definitely tight, G & W tests them under water with 15 to 20 pounds air pressure.
- Cable potheads must remain tight at all temperatures in service. To insure positive oil and moisture tightness, they are given a test with thin oil at 170° F. under 30 pounds per sq. in. pressure.
- Electric tests are also an important part of the G & W manufacturing process. You can make sure of good quality by ordering and specifying G & W cable terminating and sectionalizing devices.

Photos by Torkel Korling.

G & W ELECTRIC SPECIALTY CO., 7780 DANTE AVENUE, CHICAGO 19, ILLINOIS, U. S. A.

POTHEADS . . . BOXES . . . OIL FUSE CUTOUTS . . . OIL SWITCHES AND MULTIPLE CIRCUIT OIL DISCONNECTS

THESE FOLDERS Give You The Dope . . .

6 Page Folders with Information on——

* 1. SYNTHITE PG-1
* 2. SYNTHITE PG-4
* 3. Specifications
* 4. Methods of Insulating
* 5. Vacuum Impregnation

These folders are especially designed to help engineers, electricians, etc., in insulating electrical units. A section is devoted to the proper method of insulating units as determined by the DOLPH Laboratories. This section also gives information on pre-heating of units and dipping.

Another section will aid those who vacuum impregnate their units. The method described has generally been accepted as standard for impregnating all types of electrical units with both the conventional and synthetic insulating varnishes.

These folders are yours for the asking together with any other information you may desire regarding insulating varnishes.

JOHN C. DOLPH COMPANY

Insulating Varnish Specialists

166-8 EMMETT ST. NEWARK N. J.

REPRESENTATIVES

BOSTON
Industrial Elec. Materials Co.
204 Purchase St.

PHILADELPHIA
Elec'l Maintenance Equip. Co.
235 N. 12th St.

DETROIT
Universal Elec. Prod. Co.
905 Holden Ave.

MINNEAPOLIS
Elec'l Jobbers Equip. Co.
501 Fourth Avenue South

SAN FRANCISCO
Joslyn Company of Calif.
190 Potrero Ave.

LOS ANGELES
Joslyn Company of Calif.
5100 District Blvd.

CHICAGO
J. J. Glass and Co.
605 W. Washington Blvd.

HOUSTON
Gulf Engrg. Co., Inc.
307 M & M Bldg.,
1 Main St.

NEW ORLEANS
Gulf Engrg. Co., Inc.
916-30 S. Peters St.

ATLANTA
Mr. L. Morris Landers
309 Walton Bldg.

PITTSBURGH
Earl B. Beach Co.
First Ave. & Ferry St.

BLUEFIELD
West Va. Armature Co.

DENVER
Urquhart Service
16th Street at Blake

SEATTLE
Mr. H. S. Emanuel
1743 First Ave. So.

CLEVELAND
The R. A. Stoll Co.
1213 West Third St.

ST. LOUIS
Mr. Louis D. Moore
715 Chouteau Bldg.,
4030 Chouteau Ave.

ROCHESTER
Mr. O. P. Guthrie
423 Powers Building

MILWAUKEE
J. J. Glass and Co.
2356 N. 35th St.

How the General Electric thyratron tube makes possible the simple and accurate control of motors

LIKE some silent guiding hand, a G-E electronic tube is busy at the benches and lathes of industry — cutting production costs and speeding war output.

This tube is the thyratron, a lightning-fast automatic switch. Its job is to keep machine speed constant regardless of variations in load so that production continues without interruption.

Thus, on the cutting lathe, in turning steel parts where depth of cut varies from deep to shallow, the thyratron automatically supplies the right amount of power to hold the speed of turning exactly constant, whatever the load.

On textile looms where variation of driving speed may result in imperfect cloth, the thyratron assures a uniform motor speed for perfect weaving.

Fast to a split cycle, accurate to a hair, the thyratron is at once a synchronous switch and a rectifier that enables DC motors to operate from an AC power supply.

It is the purpose of the G-E electronic tube engineers to aid *any* manufacturer of electronic devices in the application of tubes. General Electric, through nation-wide distribution, is also prepared to supply users of electronic devices with replacement tubes.

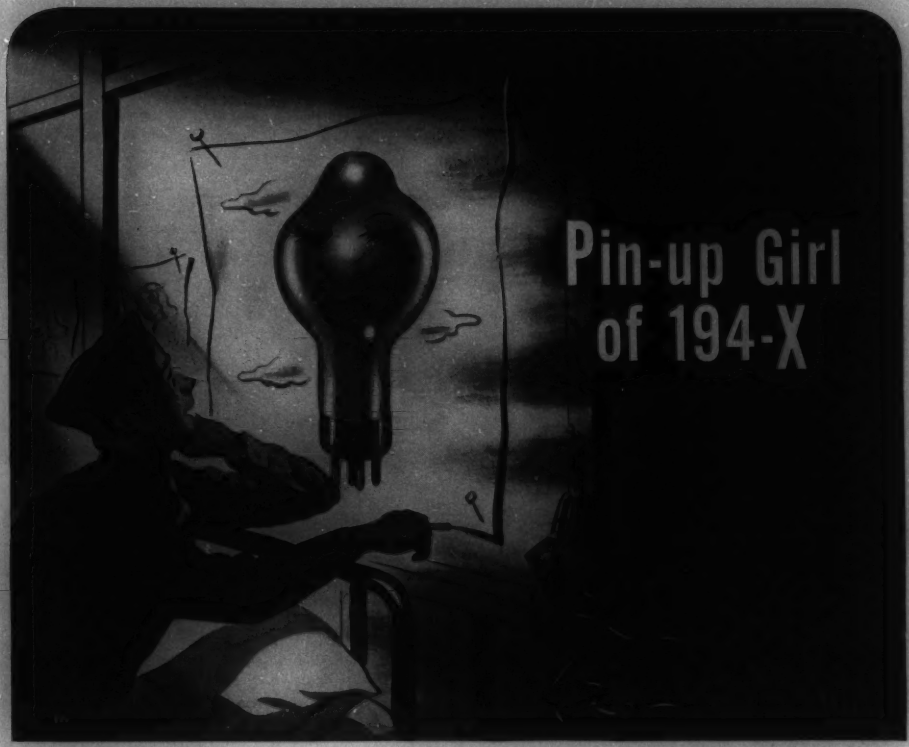
FREE BOOKLET ON ELECTRONIC TUBES

Send us the names of interested men in your plant and we will keep them informed of electronic developments. For example, we would like to mail without charge an illustrated book entitled "How Electronic Tubes Work," written in easy and understandable language, and showing typical electronic tubes and their applications. Address *Electronics Department, General Electric, Schenectady, New York.*

Tune in "THE WORLD TODAY" and hear the news direct from the men who see it happen, every evening except Sunday at 6:45 P.M. E.W.T. over CBS. On Sunday listen to "The Hour of Charm" at 10 P.M. E.W.T. over NBC.

GENERAL ELECTRIC

182-911-8880



SHE ISN'T VERY GLAMOROUS RIGHT NOW—she's much too busy winning the war to take time out for fluff. But fighting men on every front, in every plant will remember her. How she climbed right into coveralls and went to work—testing bullets, sorting cartons, bonding plywood, making steel . . . How she went to work at the front, too—getting messages through, helping to take pictures, saving lives through X-Ray, spotting planes, aiming guns . . .

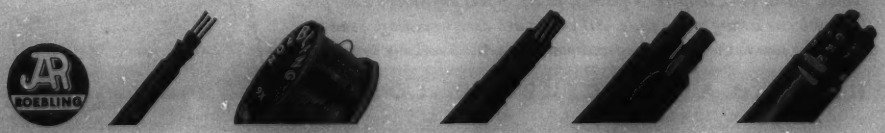
IN 194-X her popularity will be even greater. She'll have time again for glamorous jobs as well as the dirty work she's not afraid to do. She'll be making possible two-way television, piloting skyliners for weekends in Europe, producing and controlling power by radio, extending the vision of research . . .

CONCERNS IN THE ELECTRICAL FIELD that intend to go on *with electron tubes* to even newer, more exciting jobs when Victory is won will find that Roebling has been planning along those lines, too. More than planning—for in meeting war's tough specifications, Roebling is learning new things for peace.

For today's needs and tomorrow's plans rely on Roebling as your source for electrical wires and cables.

JOHN A. ROEBLING'S SONS COMPANY
TRENTON 2, NEW JERSEY
Branches and Warehouses in Principal Cities

ROEBLING
ELECTRICAL WIRES AND CABLES



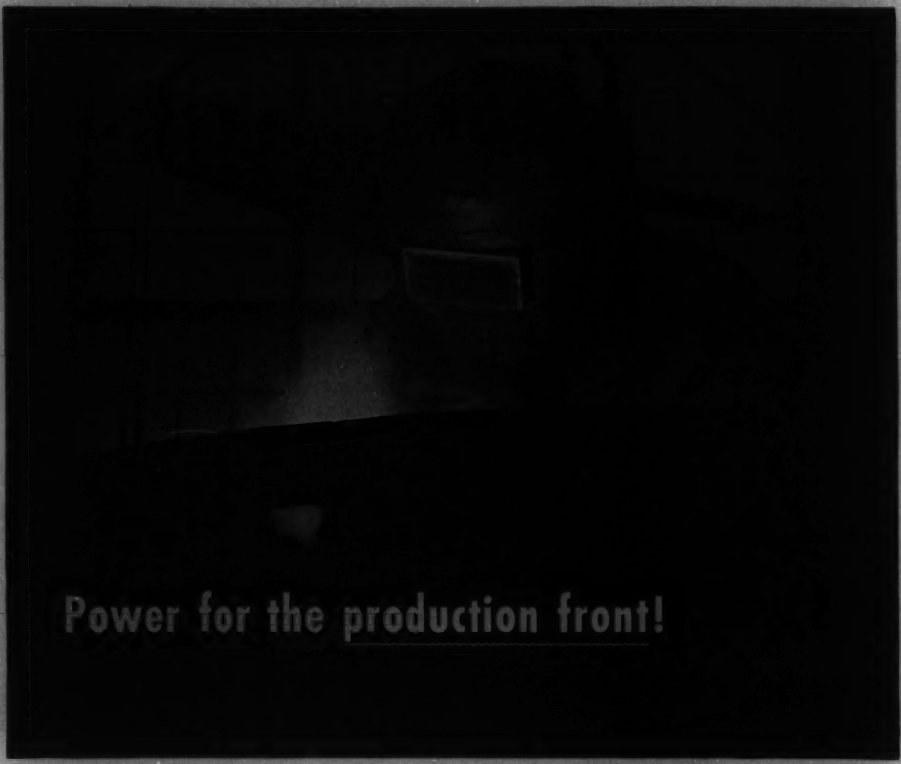
for *Permanent* resistance today and tomorrow...

Many factors contribute to the permanent performance of Ohmite Units–factors of design and construction that enable them to meet every condition of service . . . to withstand shock, vibration, heat and humidity . . . and keep going. These characteristics make Ohmite Rheostats, Resistors, Chokes and Tap Switches especially well fit for today's critical wartime needs.

What's more . . . Ohmite leadership in developing an extensive range of types and sizes has made it possible to serve innumerable applications. All this, of course, makes them readily applicable for the new peacetime products of tomorrow. Ohmite Engineers are glad to assist on any problem for today . . . or tomorrow. Write on company letterhead for helpful Industrial Catalog and Engineering Manual No. 40.

Send for Handy Ohmite Ohm's Law Calculator. *Thousands of these Ohmite Calculators are in practical use today. Figures ohms, watts, volts, amperes—quickly, easily. Solves any Ohm's Law problem with one setting of the slide. All values are direct reading. Send only 10c in coin to cover handling and mailing. (Also available in quantities.)*

OHMITE MANUFACTURING COMPANY
4803 FLOURNOY STREET, CHICAGO, U. S. A.

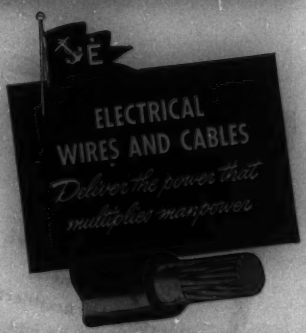


WELDING has probably contributed more to the improvement and speeding up of war production than any other single process. It saves time and money. It is a potent production weapon that women have learned to use as skillfully as men.

Here, again, electricity plays a vital role. Unfailing electric power must feed these modern tools. And unfailing power requires unfailing transmission and distribution—a job that can be entrusted only to electrical wires and cables of the finest quality.

For years, American Steel & Wire Company engineers and production experts have experimented with new methods and new materials to improve the quality of our electrical wires and cables. The war proved the soundness of this policy, for the sudden scarcity of certain critical materials did not catch us napping. New materials were available to help the conservation program without sacrifice of quality or performance. Our products were ready when the emergency came; and they'll be ready when peace comes.

For our research goes steadily on—working on new ideas and developments to take care of the increased wartime demand for power and light and the ultimate conversion to peacetime requirements.



AMERICAN STEEL & WIRE COMPANY

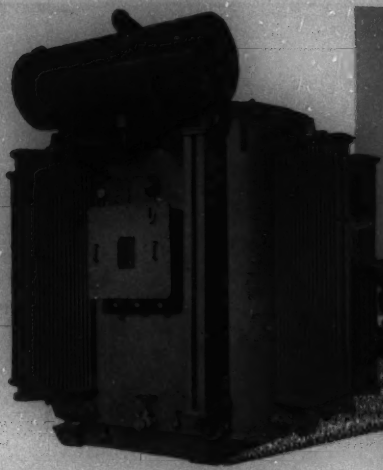
Cleveland, Chicago and New York

Columbia Steel Company, San Francisco, *Pacific Coast Distributors*

United States Steel Export Company, New York

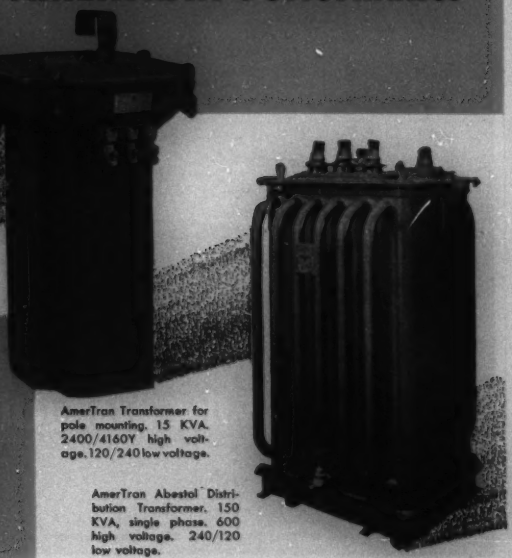
UNITED STATES STEEL

SPECIALIZATION
is the basis of
AMERTRAN Performance



AmerTran Transformer. 5000 KVA, 3-phase, 60 cycles. 13,800 high voltage, 2400/4160Y low voltage.

AmerTran Outdoor Current Transformer. 50 VA. 30 Amperes primary—5 Amperes secondary. 11,400-Y volts service.



AmerTran Transformer for pole mounting. 15 KVA. 2400/4160Y high voltage. 120/240 low voltage.

AmerTran Abestol Distribution Transformer. 150 KVA, single phase. 600 high voltage. 240/120 low voltage.

Making *only* transformers and their related products for forty-two years has meant giving continued satisfaction—gaining increased knowledge in the process—and giving, again, in improved AmerTran products.

In these years of specialization, we have learned how to build AmerTran Transformers sturdy and long-lasting. The unusual life record of AmerTran Transformers has been effected simultaneously with a constant increase in efficiency, by the proper coordination of materials at the disposal of our engineers.

And we have obtained a broad knowledge of transformer applications as well. The outgrowth of that knowledge is a host of special AmerTran applications. The test sets, renowned for their precision—the voltage regulators with their smooth control through 100% range, if desired—and others.

One of the great lessons of these years is that we fare best by maintaining AmerTran rigid standards of quality workmanship.

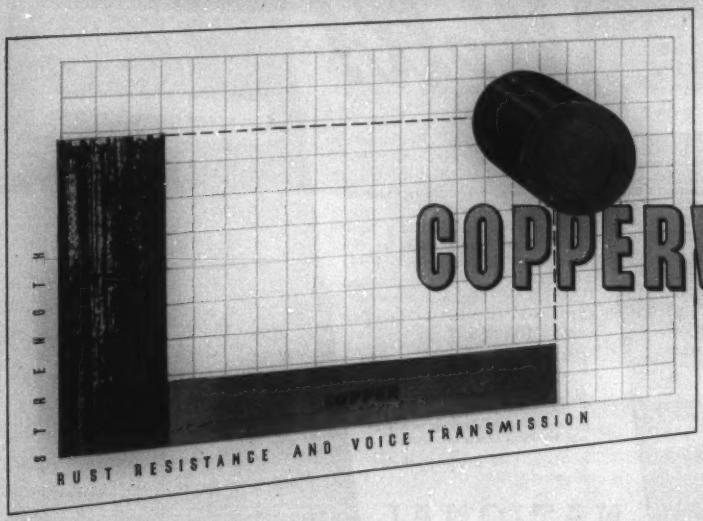
AMERICAN TRANSFORMER COMPANY
178 Emmet Street Newark, N. J.

Pioneer manufacturers of Transformers, Reactors and Rectifiers for Electronics and Power Transmission.

AMERTRAN

THE STRENGTH OF STEEL--

THE CONDUCTIVITY AND PERMANENCE OF COPPER--



It's the combination of copper and steel in Copperweld that makes it the ideal wire where strength and permanently good voice transmission are required. Steel provides strength, but lacks rust resistance and electrical conductivity. Copper provides rust resistance and conductivity, but lacks strength. The best characteristics of both metals are united in Copperweld.

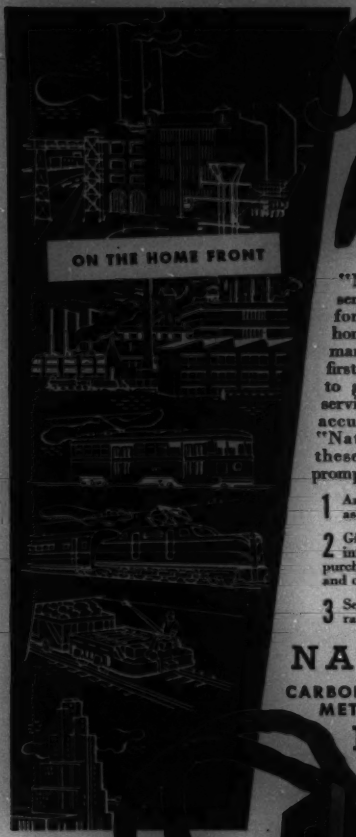
Copperweld Line Wires and Drop Wires resist rust like solid copper; both have high strength and provide permanently good voice transmission.

Copperweld Steel Company GLASSPORT, PA.

COPPERWELD LINE WIRE

COPPERWELD DROP WIRE

Serving Well!



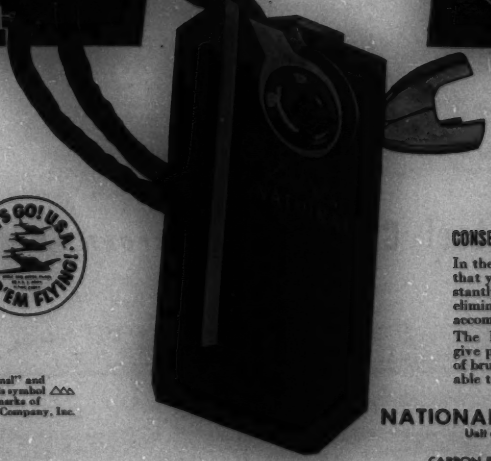
"NATIONAL" Brushes are serving well with our armed forces and with industry at home. While the immediate demands of the emergency come first, every effort is being made to give all our customers the service to which they have been accustomed. When ordering "National" brushes observe these precautions to insure prompt delivery.

1 Anticipate your needs and order as far in advance as possible.

2 Give complete and accurate information on your original purchase order. Include samples and drawings when necessary.

3 Secure best possible priority rating.

NATIONAL
TRADE-MARK
CARBON, GRAPHITE AND METAL-GRAPHITE BRUSHES



LET'S GO! U.S.A. KEEP 'EM FLYING!

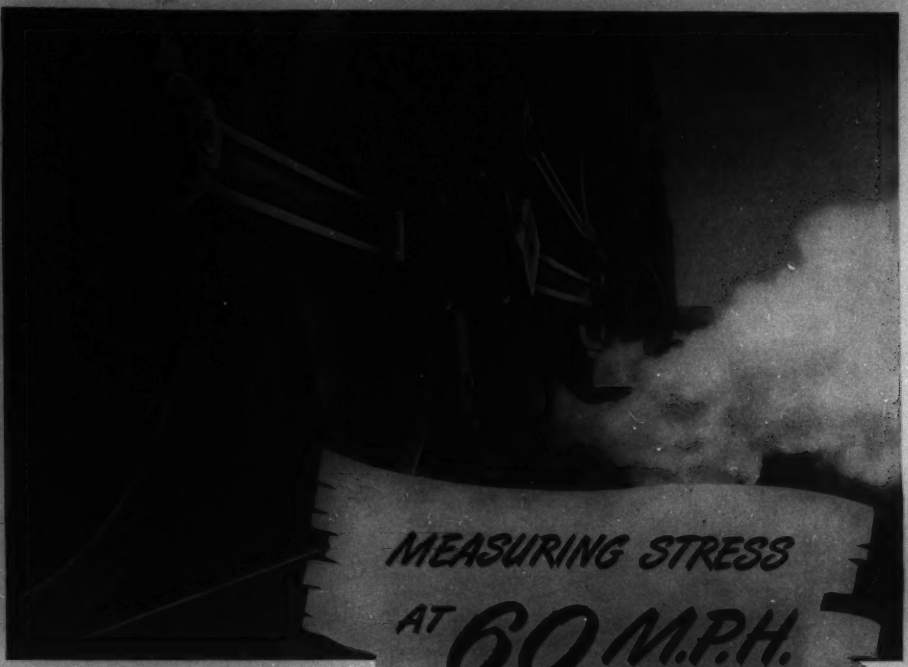
CONSERVATION AND CARE WORK HAND IN HAND

In the present emergency it is particularly essential that your electrical equipment be kept running constantly and at full efficiency. Proper cleaning and elimination of minor faults will do much toward accomplishing this objective.

The Modern Pyramids Bulletins pictured above give practical suggestions on care and maintenance of brush-using electrical equipment. They are available to you without charge.

The word "National" and the three pyramids symbol △△△ are trade-marks of National Carbon Company, Inc.

NATIONAL CARBON COMPANY, INC.
Unit of Union Carbide and Carbon Corporation
UCC
CARBON PRODUCTS DIVISION, CLEVELAND 1, OHIO
General Offices: 30 East 42nd St., New York, N. Y.
Branch Sales Offices: New York - Pittsburgh - Chicago - San Francisco



CALLS FOR IRC RESISTORS

A locomotive driving-rod packs plenty of power as it hurtles its heavy load over the rails. To detect and accurately measure stress changes in driving rods, under actual running conditions, presented an exciting challenge to engineering ingenuity. Heretofore such data was approximated through polaroid means or empirical formulas, based on scale models.

ANOTHER IRC DEVELOPMENT

Research on the intricate device finally evolved, indicated the need for a very thin resistance element of uniform characteristics . . . sensitive enough to accept every stress modification yet sufficiently stable so that readings made from time to time would be comparable I R C engineers solved the problem by a unique application of I R C's exclusive Metallized coating to a non-conductive plastic strip.

If you are confronted with a question involving resistances, why not consult I R C, the company that makes resistors of more types, in more shapes, for more uses than any other manufacturer in the world?

PREFERRED FOR PERFORMANCE • IRC • FIXED & VARIABLE RESISTORS

INTERNATIONAL RESISTANCE COMPANY

427 N. BROAD STREET • PHILADELPHIA

Vol. 6
1943

AHEAD

MAN reached for the stars and grasped . . . Electronics.

Devoted now to war, this amazing science promises wondrous adventures for mankind on THE ROAD AHEAD.

As constant research has developed the potentialities of Electronics, so the search for a BETTER WAY, here at American Lava, has perfected steatite insulation best suited to the new requirements.

Pioneers of steatite electrical insulation . . . now in our 41st year of Ceramic Leadership, we are able to say with full confidence that ALSIMAG Steatite Insulators represent the highest quality, precision, dielectric properties and mechanical strength to be found among the Steatites.

There will be no compromise with quality in the production of ALSIMAG Steatite Insulators.

AMERICAN LAVA CORPORATION

CHATTANOOGA, TENNESSEE

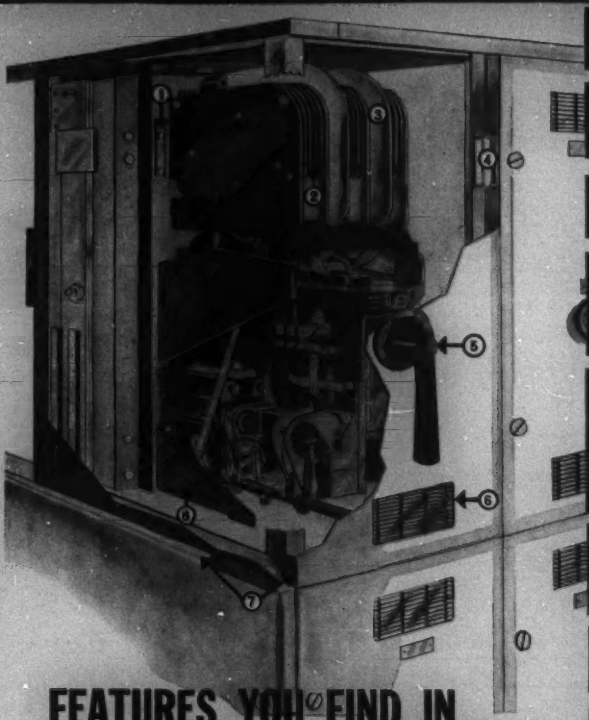
ARMY E NAVY AWARDED JULY 27, 1942

Where stability is an important requirement, ALSIMAG Steatite ceramics are unsurpassed for lending rigidity and permanence of alignment to electronic circuits.

ALSIMAG

STEATITE CERAMIC INSULATORS

CHARACTERISTICS TAILORED TO YOUR REQUIREMENT



① LIFTING HOOK—for ready removal of the circuit breaker for inspection, using overhead crane or portable hoist.

② ARC CHUTES—Magnetic blowout construction provides rapid, safe extinction of arcs from short circuits or heavy overloads.

③ INSULATING BARRIERS—provide phase insulation additional to that furnished by arc chutes.

④ HINGES—To permit ready drawout of circuit breaker for inspection, hinges allow door to open 100 degrees. They are invisible when door is closed and are slotted to permit individual alignment and adjustment of the door.

⑤ ROTARY DOOR HANDLE—attached to hinged door, provides both closing and tripping. Disengages automatically from circuit breaker when door is opened. Thumb-operated locking plate in the top can be raised when handle is in trip position to hold up to three padlocks for protection of workmen against energizing of line before clearance is given.

⑥ GRILLE-TYPE LOUVERS—at top and bottom of each door, provide ample air circulation, dissipating heat from series coils. Baffle design helps in keeping out dust.

⑦ FLANGED DOORS AND PANELS—make rigid, non-warping members without use of needlessly heavy-gauge sheet.

⑧ BASE FOOT—makes the circuit breaker a self-standing unit when removed from compartment and placed on floor or inspection bench.

FEATURES YOU FIND IN I-T-E DRAWOUT SWITCHGEAR

As a method of clearly showing hidden parts, the I-T-E Engineering Department offers this perspective cut-away drawing which has advantages over either photographic or the usual mechanical treatment. We plan a series of these to make the clearest possible explanation of Multumite advantages.

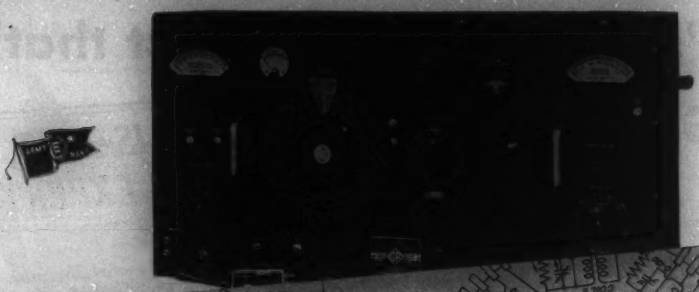
Multumite switchgear assemblies are completely metal-enclosed structures in which I-T-E incorporates many features, including those above, for safety and convenience in control and distribution of electric power. Write for Bulletin 4207—a thorough description of I-T-E Multumite drawout switchgear.

AIR SWITCHGEAR

IMMERSED IN AIR • ENCASED IN STEEL

I-T-E

CIRCUIT BREAKER CO., PHILADELPHIA, PA.



STANDARD-SIGNAL GENERATORS
by General Radio

SINCE General Radio pioneered the first commercial standard-signal generator in 1928, it has been the aim of our design engineers to make available signal generators for testing all types of home, commercial and military receivers.

In addition to standard catalog models, many specialized instruments have been designed and built for the armed services, in peace time as well as in war.

Present designs collectively cover a frequency range of 300,000:1. While many of these are not at present available for general use, because of wartime secrecy requirements, they contribute to the stock of engineering design experience that will be applied to the production of commercial models after the war.

The country's leading radio receiver laboratories are equipped with General Radio signal generators, backed by 28 years' experience in building high-quality instruments.

GENERAL RADIO COMPANY

Cambridge 39, Mass.
NEW YORK 6 • LOS ANGELES 38

Here's one Nazi broadcast that's the Gospel Truth!

U.S. TANK IS BEST, SAY NAZI EXPERTS

Germany Will Doubtless Copy Gyroscopic Feature of General Sherman Tank, Berlin Radio Declares

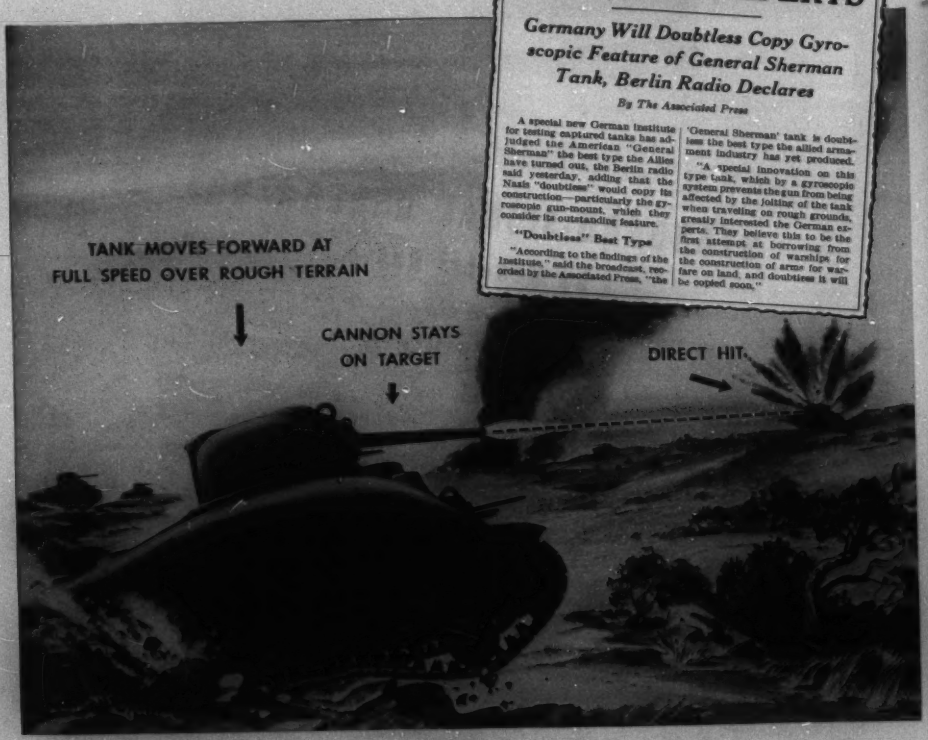
By The Associated Press

A special new German institute for testing captured tanks has adjudged the American "General Sherman" the best type the Allies have turned out, the Berlin radio said yesterday, adding that the Nazis "doubtless" would copy its construction—particularly the gyroscopic gun-mount, which they consider its outstanding feature.

"Doubtless" Best Type

"According to the findings of the Institute," said the broadcast, recorded by the Associated Press, "the 'General Sherman' tank is doubtless the best type the allied armament industry has yet produced.

"A special innovation on this type tank, which by a gyroscopic system prevents the gun from being affected by the jolting of the tank when traveling on rough grounds, greatly interested the German experts. They believe this to be the first attempt at borrowing from the construction of warships for the construction of arms for warfare on land, and doubtless it will be copied soon."



WHEN THE GERMAN RADIO paid glowing tribute to the General Sherman tank—for once it was telling the truth.

You see, tank battles used to be stop-and-go affairs, because a tank's heavy cannon could be aimed accurately *only when the tank was at a complete standstill.*

That was bad—because every stop naturally made the tank a juicy target for the enemy.

Then the Army Ordnance Department called on American industry for the solution of this problem. So the men of Westinghouse went into a huddle. And out of it came what has been called one of the greatest military developments of this War—a tank gun stabilizer that permits *incredibly accurate fire while the tank is charging ahead at full speed over rough ground!*

And then, to button up the job, Westinghouse went into production on these gun stabilizers so fast and so thoroughly that almost before you could say "El Alamein," they were being produced in sufficient quantity to equip every American tank!

No wonder the Germans thought well of the General Sherman. And no wonder they considered its gun stabilizer its outstanding feature. For this one device has revolutionized the whole combat technique of tank fighting!

For us, tank battles are no longer stop-and-go affairs, with every stop offering the enemy a "sitting pigeon." American tanks are now more than 500% deadlier than ever before.

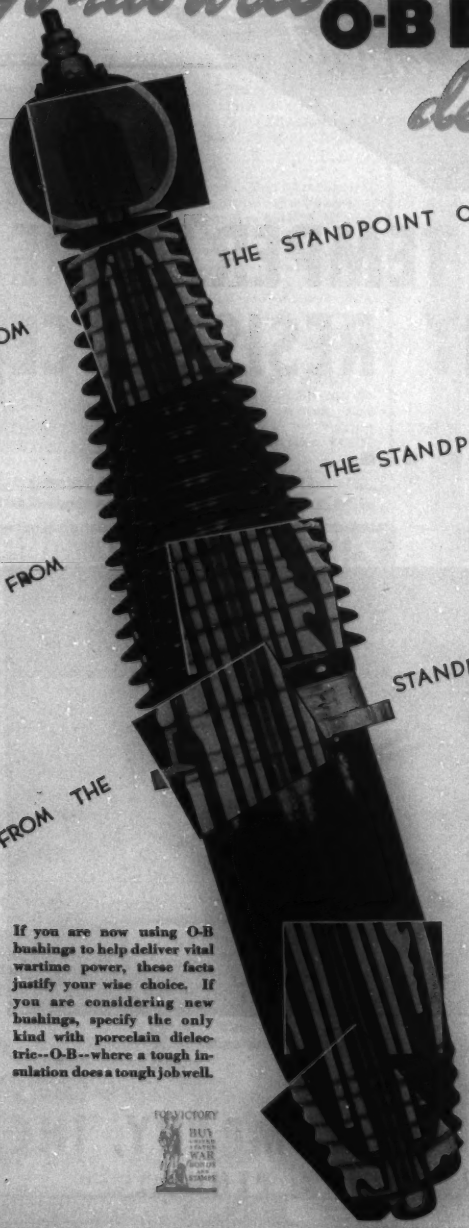
And the Westinghouse Research Laboratories, which developed the device—the Westinghouse engineers, who perfected it—and the men and women of Westinghouse who make it in great numbers—are proud as Punch.

Westinghouse Electric & Manufacturing Company, Pittsburgh, Penn.

» » Westinghouse « «

PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE

What will O-B BUSHINGS deliver?



FROM THE STANDPOINT OF **SERVICE ?**

Every O-B bushing will operate continuously at its full name-plate rating and will handle overloads without break-down or progressive deterioration. The internal porcelain dielectric cannot char or burn; absorbs absolutely no moisture; and its performance as an insulation is not dependent upon the exact condition of the oil.

FROM THE STANDPOINT OF **TIME ?**

Never in all recorded history has a piece of porcelain or its related materials been known to decompose or change in any of its physical characteristics. The porcelain in O-B bushings is good to start with, and stays that way! It is a stable insulation. It assures you of consistent performance.

FROM THE STANDPOINT OF **MAINTENANCE ?**

Your O-B bushings are something to forget--except when you want more good bushings. Porcelain insulation requires no periodic inspection or testing because it is unchangeable. Air, light, and moisture are totally excluded from the oil. The problem of oil leakage has been effectively met by O-B's compression spring assembly that also relieves all porcelain parts of destructive strains. Visual inspection tells you all you want to know about O-B bushings.

If you are now using O-B bushings to help deliver vital wartime power, these facts justify your wise choice. If you are considering new bushings, specify the only kind with porcelain dielectric--O-B--where a tough insulation does a tough job well.

FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS

Ohio Brass

MANSFIELD, OHIO

CANADIAN OHIO BRASS COMPANY, LTD., NIAGARA FALLS, ONTARIO

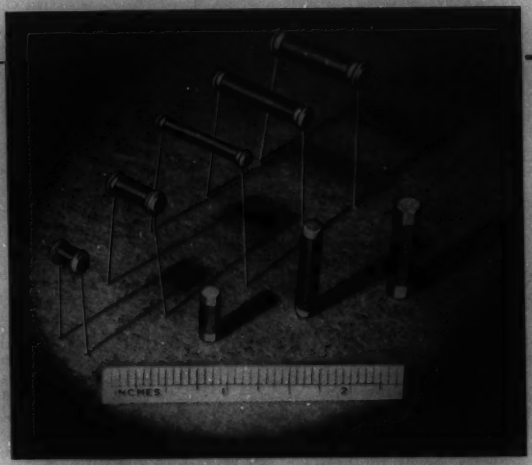
B411-91

KEYSTONE'S *New Development*

NEGATIVE TEMPERATURE COEFFICIENT RESISTANCE MATERIAL . . .

DEVELOPED to compensate for electrical resistance changes due to temperature variations—to reduce or eliminate initial current surge in electrical equipment—to provide various degrees of time delay in electrical units—used as a remote unit for temperature measurement, etc. . . .

Write for information.



Representative units

Manufactured by

KEYSTONE CARBON COMPANY, INC.

SAINT MARYS . . . PENNA.

QUICK CURRENT MEASUREMENTS

WITH A

TONG TEST AMMETER

Increased production and time are, perhaps, two of the most important factors in our nation's war effort. That's why a TONG TEST AMMETER should be standard equipment in every plant doing any kind of war work..

This remarkable, portable instrument saves valuable hours because it measures both A. C. and D. C. up to 800 amperes in less than five seconds without necessitating a break in circuit or insulation. This almost unbelievable speed enables maintenance men to keep a closer check on current loads and, thus, keep productive machinery working at top speed.

Weighing only 2¼ pounds, a TONG TEST AMMETER can be used anywhere by anyone. Get the complete facts by writing today for a copy of the TONG TEST bulletin.

COLUMBIA ELECTRIC MFG. CO.
4519 Hamilton Ave. Cleveland, Ohio

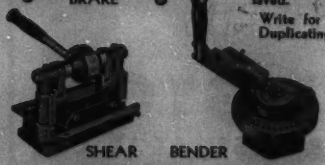
TONG TEST AMMETERS

DIE-LESS DUPLICATING

FOR EXPERIMENTAL PARTS OR TEST RUNS

The parts shown are typical of the great variety of simple or intricate forms and shapes which can be quickly duplicated to a tolerance of .001" with DI-ACRO Precision Machines—Shears, Brakes, Benders. For experimental and research work or production runs, DI-ACRO Units form bi-metals, dielectrics, sensitized materials, varnished cambrics, fiber slot insulation, frequency reeds; angle, channel, tube, rod, moulding, wire, strip stock; shear stock sheets, trim duplicated stampings. With DIE-LESS DUPLICATING, Man Hours and Critical Materials are regularly saved.

Write for Catalog—"Metal Duplicating Without Dies"



O'NEIL-IRWIN DI-ACRO MFG. CO.
250 Eighth Ave., South
Minneapolis 15, Minnesota

MORGANITE BRUSHES

dependability on "both" fronts!

Industrial production and military offensives are on common ground—both being dependent upon peak efficiency for ultimate success. That is why MORGANITE brushes are being extensively used on 'both' fronts.

Smooth, quiet operation with negligible sparking, energy loss and commutator wear, is inherent with these quality electromotive components.

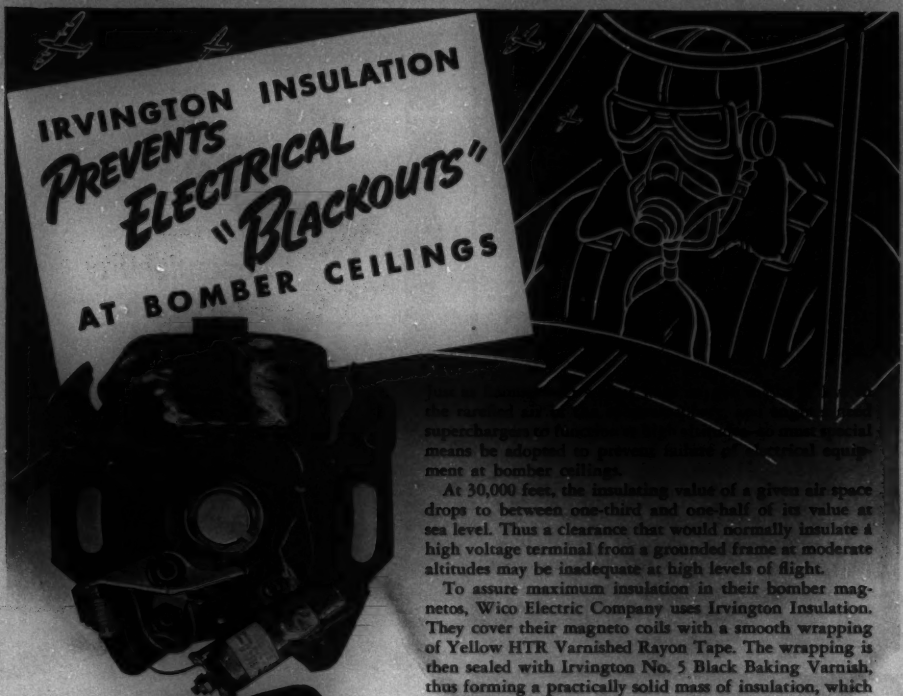
Check MORGANITE now for your motor, generator and dynamotor requirements; you'll find it wherever continuous performance is a prime requisite.

WRITE FOR DATA BOOKLET

The MORGANITE 30-page informative booklet is available on request without obligation. The correct type, body, material and application are described in detail.

MORGANITE BRUSH CO.
INCORPORATED
LONG ISLAND CITY, NEW YORK

IRVINGTON INSULATION PREVENTS ELECTRICAL "BLACKOUTS" AT BOMBER CEILINGS



At 30,000 feet, the insulating value of a given air space drops to between one-third and one-half of its value at sea level. Thus a clearance that would normally insulate a high voltage terminal from a grounded frame at moderate altitudes may be inadequate at high levels of flight.

To assure maximum insulation in their bomber magnetos, Wico Electric Company uses Irvington Insulation. They cover their magneto coils with a smooth wrapping of Yellow HTR Varnished Rayon Tape. The wrapping is then sealed with Irvington No. 5 Black Baking Varnish, thus forming a practically solid mass of insulation, which maintains its dielectric strength regardless of low atmospheric pressure and making the coil "short proof" at 30,000 feet as well as at sea level.

Winding Wico Magneto Coil assembly with Irvington Yellow HTR Varnished Rayon prior to dipping in Irvington Varnish. This special precaution prevents the spark from shorting and grounding—which the lower air resistance of high altitudes would normally permit.

To eliminate air pockets by forming a practically solid mass of insulation, Wico coils are dipped in No. 5 Black Baking Varnish. Wico has found it to be the best insulator for the job.

IRVINGTON YELLOW HTR VARNISHED RAYON

an excellent alternate for varnished silk, is light in weight, flexible and elastic. Has excellent resistance to oil, moisture and heat. Tensile strength—15 lbs. per inch width (warp direction). Dielectric strength—1200 volts per mil of total thickness. Comes in straight cut or bias cut; thicknesses from .003" to .008", widths from ¼" to 36".

IRVINGTON No. 5 BLACK BAKING VARNISH

is composed of vegetable drying oils, heat treated and chemically combined with selected asphalts and pitches. Bakes quickly—retains elasticity indefinitely—waterproof—high acid and alkali resistance. Is recommended for treating assembled armatures, stators and coils.

For further information and samples, or for technical assistance on unusual problems, write Dept. 36.

IRVINGTON
VARNISH & INSULATOR CO.
IRVINGTON, NEW JERSEY, U. S. A.

PLANTS AT IRVINGTON, N. J. & HAMILTON, ONT., CAN. • *Representatives in 20 Principal Cities*

Oil capacitor rated at 15,000 v. 15 mfd. Side terminal reduces headroom. Typical "bathtub" also shown for comparison.

WAR, *today;* *tomorrow,* PEACE

● From tiny "bathtubs" to huge high-voltage units, Aerovox oil capacitors are meeting today's military and wartime industrial needs. Subject to high priorities, of course.

A tremendous production capacity is making oil capacitors commonplace. Drastic wartime service is making such capacitors more rugged than ever. Thus many electrical, electronic and industrial applications will benefit from such war development, in tomorrow's peace.

The new Aerovox Capacitor Catalog lists an exceptional choice of capacitors. Write on business stationery for your copy.

AEROVOX *Capacitors*

INDIVIDUALLY TESTED

GET THIS COMPLETE LAFAYETTE *Catalog*

A single order (no matter how large or how small) to Lafayette Radio Corp. will bring *prompt* delivery of the radio parts and equipment you may need. Lafayette Radio Corp. is *headquarters* for all radio and electronic parts and equipment of every nationally known manufacturer in the field.

Thousands of manufacturers, electronic engineers and private and military training program directors know Lafayette's reputation for complete stocks and extensive procurement facilities. We can fill your needs too . . . *quickly!*

Write today for FREE 130 page Radio and Electronic Parts and Equipment Catalog . . . Address Dept. 9-C-3

LAFAYETTE RADIO CORP. CHICAGO

LAFAYETTE RADIO CORP.

901 W. JACKSON BLVD. CHICAGO, ILLINOIS
265 PEACHTREE STREET, ATLANTA, GEORGIA

ARMY E NAVY

ONAN

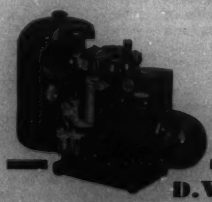
ELECTRIC PLANTS

Electricity for Any Job—Anywhere!

ONAN GASOLINE DRIVEN ELECTRIC PLANTS provide electricity in any location where it is not otherwise available, and for emergency and standby service.

Thousands of these reliable, sturdy plants are doing a winning job on all the fighting fronts by providing power and light for many vital war tasks.

Ratings from 350 to 35,000 watts. A.C. 50 to 800 cycles, 110 to 660 volts. D.C. 6 to 4000 volts. Also dual A.C. and D.C. output models. Air or water cooled engines.



Details gladly furnished on your present or post-war need for Electric Plants.

D. W. Onan & Sons

1932 Royalston Ave., Minneapolis, Minn.

Typical oscillograph for a given powder sample, showing matrix of dots providing an accurate reference or coordinate system for the burning powder graph, permanently photographed.

Straight Shooting...

★ DuMont Type 235 cathode-ray oscillograph is being used in conjunction with a closed-bomb method of powder testing. Signals for the oscillograph are generated by the closed-powder bomb. Potentials furnished by burning powder provide the horizontal and vertical deflection signals. Luminous dots electronically imposed on the screen provide an accurate calibration means. The resultant combination oscillogram is photographed, as shown above, for a permanent record.

Thus each lot of powder, whether experimental or in production, can be checked for vital burning qualities. Uniformity is assured. Our gun crews "out there" can be confident that their powder charges are *right*.

All of which is but another example of how DuMont specialists work with technicians in many different fields, in the application of cathode-ray technique.

★ Submit your cathode-ray problem. Write on business stationery for new manual and catalog

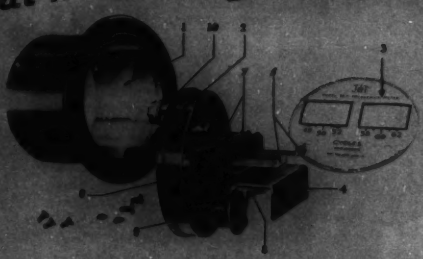
DUMONT

ALLEN B. DU MONT LABORATORIES, INC.

Passaic, New Jersey

Cable Address: Wesporlin, New York

What makes it RESONATE?



J-B-T Model 30-F Vibrating Reed Frequency Meter with case removed

1. Case
2. Base
3. Dial
4. Mounting Frame
5. Spring Steel Reeds
6. Reed Mounting Bar
7. Driving Coil
8. Permanent Magnet
9. Series Resistor
10. Terminal Studs

HOW DOES IT WORK? By resonance. As the current flows through the driving coil, the frequency with which the current alternates or is interrupted determines the number of magnetic pulls per second on the reeds. Each reed is preset during manufacture to respond to but one frequency — by combining parts of the proper strength, dimensions and weight. The reed which is "in tune" *RESONATES*, which means that it vibrates to full amplitude — the others little or not at all. Simply READ the REED, and that's your frequency.

DON'T ALL THE REEDS VIBRATE? No, not now. Since the introduction of the original principle, J-B-T basic improvements have virtually eliminated sympathetic mechanical vibration. Reeds on either side of the reed which is vibrating to *full* amplitude also vibrate, but to a much more limited extent, and actually help to indicate the frequency more accurately, particularly if it is fractional.

CAN THEY TAKE IT? Yes, sir. Thousands of J-B-T Vibrating Reed Frequency Meters now in use are standing up where the going is *tough*. Day in, day out they are measuring cycles per second, revolutions per minute, and frequencies for wartime uses.

HOW DO YOU ADJUST THE METER WHEN IN USE? You needn't. Once calibrated at the factory, it is permanently accurate. It requires no adjustment to compensate for wave form, external magnetic fields, voltage variation (±20%), or normal operating temperatures.

YOU SAY PERMANENTLY ACCURATE, BUT HOW ACCURATE? Within ±0.3% for full cycle increments, ±0.2% for half cycle increments in the 60 cycle range, for instance. A 400 cycle meter is accurate to within ±0.3%.

WHAT ABOUT POWER CONSUMPTION? It is exceptionally low, ranging from less than 2 watts at 400 cycles at 115 volts — to ½ watt at 60 cycles at 115 volts — depending on the model.

IS THE CONSTRUCTION THE SAME FOR ALL MODELS? No. These instruments are available in full range of frequencies, voltages, reed groupings and case sizes. Models are designed to fit the application. J-B-T engineers will be glad to help you get the RIGHT meter for your requirements.

Send for illustrated data bulletin VF-43

Manufactured under Triplett Patents and/or Patents Pending.

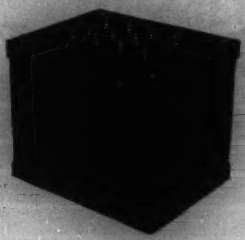
J-B-T INSTRUMENTS, INC.

441 CHAPEL STREET • NEW HAVEN 8, CONNECTICUT

J-BT-2

electronic TRANSFORMERS

Acme electronic transformers are made-to-measure, for each application. That's why independent, unbiased tests give Acme first choice in performance. Acme engineers combine exact electrical specifications with mechanical limitations into precision-made transformers that provide for maximum performance of the electronic device.

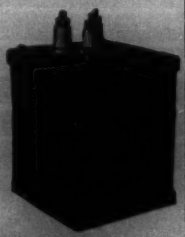


POWER OR FILAMENT TRANSFORMERS

Acme case designs require minimum mounting area. May be mounted on bottom, or suspended from top or side. Produced to specifications in sizes from 50 VA to 500 VA.

FILAMENT TRANSFORMERS

Type T-7025 Acme Filament Transformer for 2—866 Rectifier Tubes. Requires minimum mounting space; mounting centers for 25 VA, only 3" x 3¼", height 5¾. Precision-made to specifications in production quantities in ratings from 25 VA to 1½ KV.



MINIMUM WEIGHT AIR-BORNE TRANSFORMERS

Acme compound-filled, sealed case Audio, Driver, Interstage transformers, Reactors and Microphone input transformers are built to withstand and satisfactorily perform under extreme temperature variations. Bulletin 159 tells why. Write for your copy today.

THE ACME ELECTRIC & MFG. CO.
22 WATER ST. CUBA, N. Y.

Acme Electric TRANSFORMERS

...ASES
...L STEEL BASES
...tter Sealing and Shielding

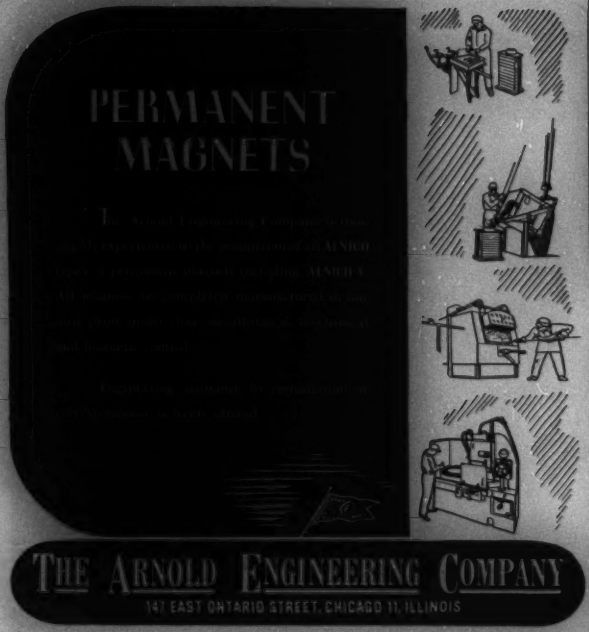
...ecently developed type of base for drawn steel case ...ransformers has greatly improved sealing and shielding.

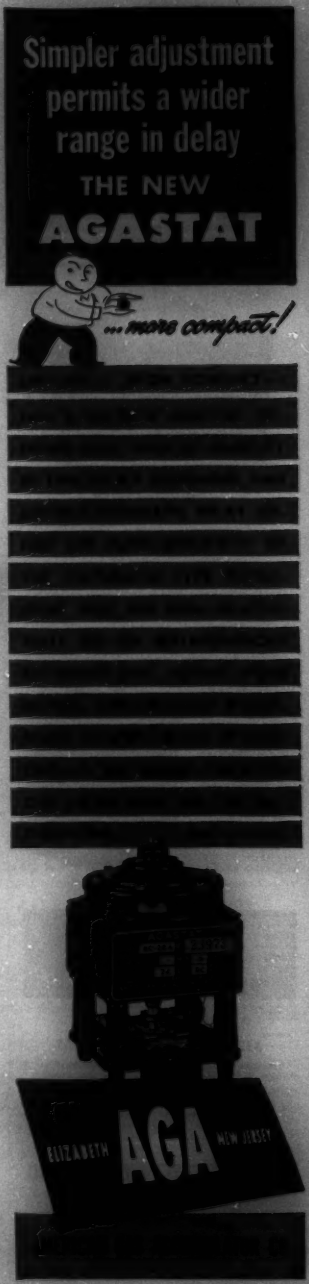
The new drawn steel base has a deep lip that is stamped to close tolerance with the case interior and press fitted to position.

The results are a deeper internal seal, stronger and more uniform, due to solder seepage into the fitted seams, and better shielding because true metal to metal—case to base contact has been established.

If your problem is one of finding transformers that will withstand unusual conditions—Write Today.

CHICAGO TRANSFORMER CORPORATION
3501 WEST ADDISON STREET • CHICAGO





CLASSIFIED ADVERTISEMENTS

RATES: Sixty cents per line; minimum charge based on use of five lines; maximum space not to exceed thirty-five lines. Copy is due the 15th of the month preceding publication date.

WANTED
ENGINEERS and TECHNICIANS

A well established Tulsa, Oklahoma, concern is in urgent need of:

Engineers who have had experience in design and development of electronic equipment;

Engineers who are experienced in the mechanical design of small precision equipment, and are familiar with shop practice and tools;

Engineers who are experienced in laboratory development of both electrical and mechanical equipment and their components;

Technicians for assembly and construction of electrical and mechanical instruments.

If your abilities are not being fully utilized in War Industries, write us to-day giving full details of past experience, education, age, draft status and salary expected. Recent graduates and female applicants will be given full consideration. All applicants must be Citizens of the United States and must have W. M. C. certificate of availability. Address Box 282, Electrical Engineering, 33 West 39th Street, New York (18), N. Y.

INSTALLATION ENGINEER, for Electronic Induction Heating Equipment. Traveling. Radio experience desired. Permanent. If now in war work at full skill, do not apply. Address Box 274, Electrical Engineering, 33 West 39th Street, New York (18), N. Y.

ELECTRICAL and MECHANICAL ENGINEER, with approximately 20 years experience in designing all sizes of transformers in distribution and power sizes, desires position with electrical manufacturing company. Familiar with mechanical and insulation problems and capable development engineer. Not at present time on work using full capabilities. Willing to travel but would prefer location in the East. Address Box 273, Electrical Engineering, 33 West 39th Street, New York (18), N. Y.

SALES ENGINEER—ELECTRICAL, having good following in Marine and Industrial field. Would consider additional lines in Los Angeles or Pacific Coast. Address Box 277, Electrical Engineering, 33 West 39th Street, New York (18), N. Y.

RECENT EVENING GRADUATE, E.E., desires position in electrical engineering and design department. Experience: 3½ years with large manufacturer of heavy duty and special motors and generators, including extensive engineering and shop experience. Thorough training in electronics, A.C. and D.C. machinery. Address Box 278, Electrical Engineering, 33 West 39th Street, New York (18), N. Y.

Specialists for over a generation in

OIL IMMERSED MOTOR CONTROL

ROWAN CONTROL
THE ROWAN CONTROLLER CO., BALTIMORE, MD.

CLASSIFIED ADVERTISEMENTS

WANTED

Graduate Electrical Engineer with Research and manufacturing experience in dielectrics and mica capacitor production as applied to radio communications field. Midwest location. Excellent opportunity for permanent association. Address Box 279, Electrical Engineering, 33 West 39th Street, New York (18), N. Y.

WANTED: Man experienced in steam generation and personnel matters as assistant superintendent of production for large public utility in the Southeast. Must be technical graduate. Experienced, capable man will find opportunity for advancement. Address Box 280, Electrical Engineering, 33 West 39th Street, New York (18), N. Y.

ELECTRICAL ENGINEER WANTED: Man with several years experience in Electrical Design Engineering of fractional horsepower, AC motors and generators. Should be able to develop a new line of motors and carry on development work in the Research & Development Department of a concern in the middle-west who is progressing rapidly in this field. A good chance for steady work and high wages. Concern now in the process of developing a new line of post-war specialized Rotary Electrical Equipment. Please write giving full details of experience, education, age, draft status and salary expected. Address Box 281, Electrical Engineering, 33 West 39th Street, New York (18), N. Y.

WANTED: Assistant superintendent by public utility for large steam electric generating plant in the Southeast. Must be technical graduate and have ability to handle personnel. Opportunity for advancement for experienced, capable man. Address Box 275, Electrical Engineering, 33 West 39th Street, New York (18), N. Y.

TWO IMPORTANT PERMANENT ENGINEERING POSITIONS ARE OPEN

Connecticut Telephone & Electric Division of Great American Industries, Inc. needs two experienced men in its Meriden, Connecticut plant.

The first man should have a thorough knowledge of acoustics and experience with magnetic circuits and acoustical measurements.

The other man must be familiar with the application and molding techniques of plastics. He should have several years of design experience on small electrical apparatus, and an understanding of magnetic and electrical circuits.

"Connecticut Telephone" is a prime war contractor with an assured peacetime future. The two engineers described above will work on both wartime and post war projects. Write, phone or wire Mr. William R. Curtiss, Chief Engineer, Connecticut Telephone & Electric Division, Great American Industries, Inc., Meriden, Connecticut.

Persons in Essential Activity or Critical Occupation not considered without statement of availability.

GREAT AMERICAN INDUSTRIES, INC.
70 BRITANNIA STREET MERIDEN, CONNECTICUT

Where signal lights should never fail

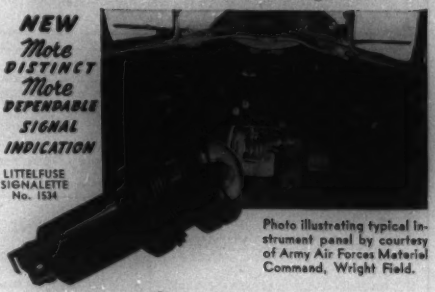


Photo illustrating typical instrument panel by courtesy of Army Air Forces Materiel Command, Wright Field.

Littelfuse SIGNALETTE

"Butterfly" Open Signaling

"Butterfly" Closed No Signal

Littlefuse Signalette is an entirely new light signal indicator for industrial uses, and aircraft; in aircraft for signal indication on landing gear, running gear, radio, oxygen flow, fuel and oil pressures, etc. Indicates without lamp or delicate filaments, by *reflected* light, daylight or artificial—by "black light"—and in total darkness. Positive indication in brightest sunlight or darkest night. Adapts instantly to airman's eyes. No blur, glare nor dimming. Fluorescent radium-active "butterfly" electrically energized, opens showing light in red, amber, green or white.

DOES AWAY WITH SPARES

When installed Signalette needs no further attention. It entirely eliminates costs and delays or replacements. It meets the shortage in filament lamps. Mounts in the same space as Lamp Assembly AC-42-B-3593.

Signalette has successfully withstood tests down to −85° F, and up to 155° F, under conditions equaling most severe aircraft operation.

SAVES HALF THE CURRENT

Signalette uses only 2.25 watts and draws only .09 ampere. Filament lamps average 4.5 watts. Normal high voltage surges do not burn out Signalette.

Send for Signalette Bulletin, complete engineering data, and information on test samples. Write or wire Littelfuse, El Monte Office.

LITTELFUSE INCORPORATED
260 Ong St., El Monte, California
4757 Ravenswood Ave., Chicago, Ill.

Professional Engineering Directory

BLACK & VEATCH
Consulting Engineers
Water, Steam and Electric Power Investigations, Design, Supervision of Construction, Valuation and Tests
4706 Broadway KANSAS CITY, MO.

SANDERSON & PORTER
ENGINEERS
FINANCING—REORGANIZATION—DESIGN—CONSTRUCTION of INDUSTRIALS and PUBLIC UTILITIES
Chicago New York San Francisco

REG. 1911 MEM. A.I.E.E.
CHRISTIAN E. BROWN
Electrical Engineer
DESIGNS—SPECIFICATIONS—REPORTS
Tel. 6604 MANCHESTER, CONN.

SARGENT & LUNDY
ENGINEERS
140 South Dearborn Street
CHICAGO, ILLINOIS

Member A.I.E.E.
JULIEN H. DAVIS
Consulting Engineer
Industrial
Utility—Electrical—Mechanical
740 So. Broadway Los Angeles, Calif.

THE J. G. WHITE Engineering Corporation
Design—Construction—Reports—Appraisals
80 BROAD STREET NEW YORK

FRANK F. FOWLE & CO.
Electrical and Mechanical Engineers
35 East Wacker Drive CHICAGO

Numerous readers of ELECTRICAL ENGINEERING (this edition 23,400 copies) frequently require the services of a consulting engineer. Through this directory, the professional consultant can keep his name constantly before these readers, at small cost. Rates on request.

JACKSON & MORELAND
Engineers
Public Utilities—Industrials
Railroad Electrification
Designs and Supervision—Valuations
Economic and Operating Reports
BOSTON NEW YORK

J. W. WOPAT
Consulting Engineer
TELEPHONE ENGINEERING
Construction Supervision
Appraisals—Financial
Rate Investigations
1510 Lincoln Bank Tower, Ft. Wayne, Ind.

Z. H. POLACHEK
Reg. Patent Attorney
Professional Engineer
PATENTS OBTAINED & SEARCHED
for any invention in U. S. Pat. Off.
1234 Broadway Phone
(At 31 St.) NEW YORK Longacre 5-3088

J. G. WRAY & CO.
Engineers
Utilities and Industrial Properties
Appraisals Construction Rate Surveys
Plans Organizations Estimates
Financial Investigations Management
105 West Adams St., Chicago

ELECTRICAL ENGINEER

Position available for outstanding Electrical Engineer. The work involves research and development in the application of Plastics in the electrical field.

Experience in the manufacture of insulated wire or cable preferred.

Age 25 to 35. Draft classification—3A or better.

Education—E.E. degree from a good technical university. Must be technically proficient. Not a duration job.

Application must be complete including age, college, year graduated, degree, present employer, salary and salary expected. Also inexpensive photograph.

If employed in essential activity within the past 30 days, do not apply unless in possession of statement of availability from previous employer or the War Manpower Commission. Address Box 276, ELECTRICAL ENGINEERING, 33 West 39th St., New York (18), N. Y.

PERMANENT MAGNETS

LITTLE Changes Can Make A BIG Difference

But the important thing is—where and how changes in the design of permanent magnets should be made. That takes knowledge of the subject of magnetism.

Perhaps our long experience in this field would be helpful, if you are not entirely satisfied with the performance of your present magnets. And once the improved design is worked out, we can supply your requirements in ALNICO or NIPERMAG.

7-CC-4

CINAUDAGRAPH CORPORATION
STAMFORD, CONNECTICUT

Now you can eliminate the inherent difficulties encountered in soldered small wired connections by taking advantage of the newest addition to the line of Solderless AMP "Diamond Grip" Insulation Support Terminals, designed specifically for use on wire sizes 26 to 22 inclusive.

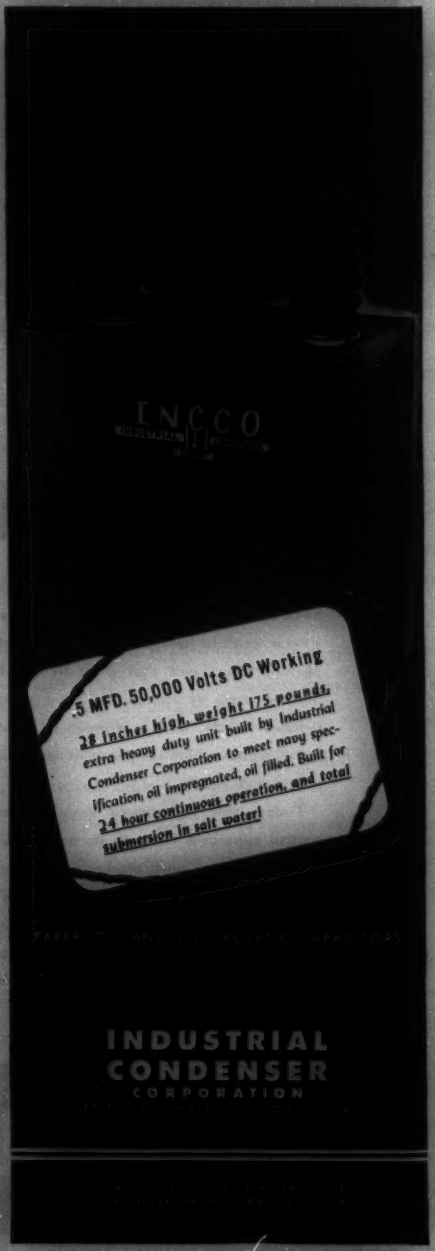
CHECK THESE ADVANTAGES AGAINST YOUR PRESENT METHODS

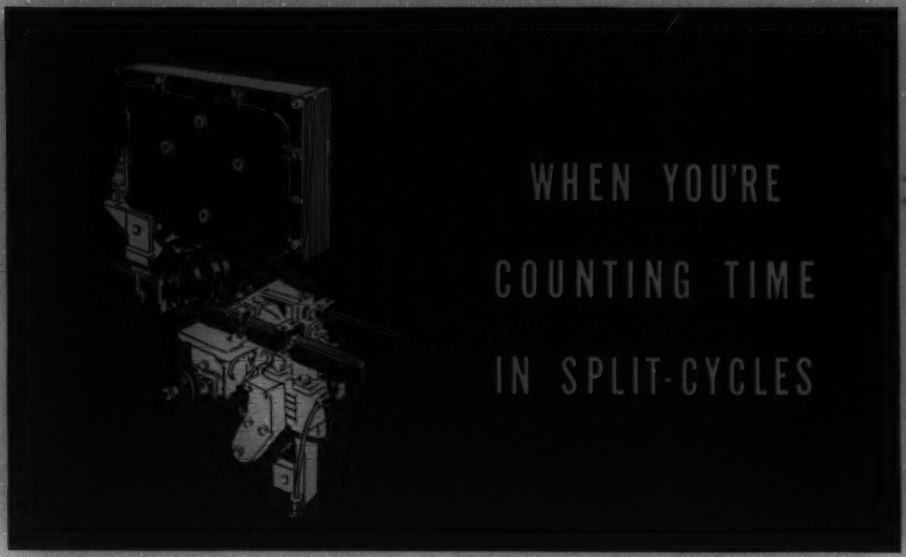
1. Eliminates skilled labor by providing self-gauging hand, foot and power installation tools which assure uniform application.
2. Three perfect crimps in a single operation.
3. Minimum voltage drop through terminal.
4. Tensile strength greater than strength of wire itself.
5. Eliminates solder joint failures, speeds up production and protects against danger of grounds or shorts.
6. Visual inspection of every connection.
7. Assured uniformity of performance through uniformity of installation.

Write, phone or wire for prices and complete details.

AIRCRAFT-MARINE PRODUCTS INC.
DEPT. E, 286 N. BROAD ST. ELIZABETH, N. J. TEL. ELIZABETH 2-1350
A & M ACCESSORIES LTD. TORONTO CANADA

TOUGH?
Not when
YOU'RE EQUIPPED
TO HANDLE THEM
Both the electrical and mechanical characteristics of UTC transformers are designed to customer's specifications. The wide variety of UTC formed, drawn, extruded and die-cost cases are augmented by complete facilities at the UTC plants for the manufacture of special sizes and shapes to exact requirements.
If you have a special problem,
may we have an opportunity to cooperate?
UNITED TRANSFORMER CO.


INCCO
.5 MFD. 50,000 Volts DC Working
28 inches high, weight 175 pounds,
extra heavy duty unit built by Industrial Condenser Corporation to meet navy specification, oil impregnated, oil filled. Built for 24 hour continuous operation, and total submersion in salt water!
INDUSTRIAL
CONDENSER
CORPORATION



Switchgear, built to function in a fraction of a cycle, can't be hampered by excess weight. Manufacturers met that issue by making moving parts of aluminum. They greatly reduced inertia, with a consequent lessening of hammer-blow. Equipment was made strong and sturdy.

Today, this high-speed switching and control apparatus is up to its neck in war work, helping to push production and protect the equipment at the same time. Tomorrow's designs will profit by the lessons learned today. The postwar era is certain to see the field of high-speed switching greatly expanded and refined.

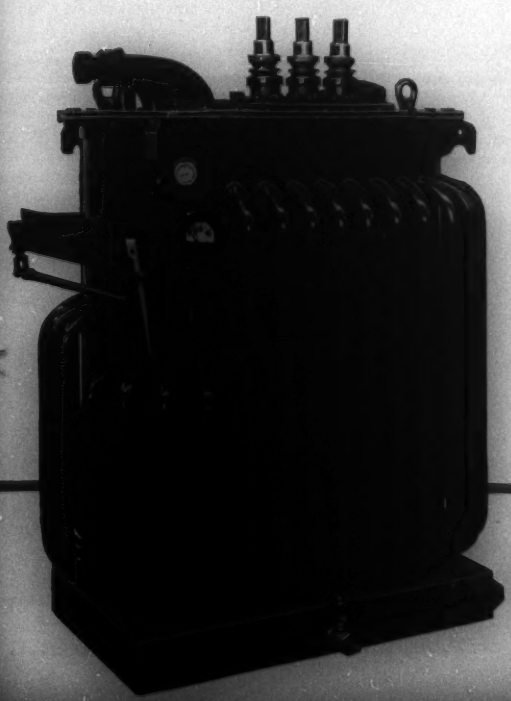
Have you considered what aluminum and its high strength alloys will do for your postwar equipment, doubtless still in the dream stage? They offer light weight with high strength and sturdiness. Aluminum has high electrical conductivity and is nonmagnetic. It is highly resistant to corrosive attack.

Operators of power lines and electrical bus systems have learned to depend on all of these properties of aluminum to improve the performance of their construction. ALUMINUM COMPANY OF AMERICA, 2149 Gulf Building, Pittsburgh, Pennsylvania.

Here are the facts for you to know about Kuhlman Saf-T-Kuhl Transformers

SAFETY: Kuhlman SAF-T-KUHL Transformers are filled with a non-inflammable, non-explosive, inert cooling fluid and are thus 100% safe.

WHERE TO USE: Kuhlman SAF-T-KUHL Transformers are designed for manufacturing plants wishing to modernize or expand their plant capacity or facilities. Kuhlman SAF-T-KUHL Transformers make it possible to divide existing electrical circuits into several sections in considerably less time and at less cost, than is possible with the usual type of transformer which requires vaults.



INSTALLATION: SAF-T-KUHLS can be installed at the load center of each section—even on beams up near the ceiling. They thereby save floor space, eliminate the need of expensive vaults, and save a great deal of the secondary copper usually required.

REGULATION: SAF-T-KUHLS improve voltage regulation, and in every other way give the same efficient, dependable performance associated with Kuhlman Transformers for over 46 years.

In addition to SAF-T-KUHLS Kuhlman builds Power, Distribution and CSP Transformers and Line Regulators. When you need transformers it will pay you to specify Kuhlman.

KUHLMAN

ELECTRIC COMPANY
BAY CITY, MICHIGAN

RCA 935—A NEW PHOTOTUBE

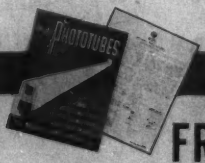
FOR PRECISE MEASUREMENT OF ULTRAVIOLET RADIATION

IF YOU deal with ultraviolet radiation and have a measurement or detection problem, RCA 935 may be of help to you. This new tube was designed by RCA engineers to give high sensitivity in the ultraviolet range—down to 2,000 Angstroms—yet to eliminate the effects of infra-red radiation. Applications already include use in the detection of certain hazardous gases, in the continuous analysis of certain solutions, and for the measurement of ultraviolet radiation *per se*. There's an RCA phototube for nearly *every* application.

The RCA 935 has an overall length of 4¼ inches (max.); max. diameter, 1-5/16 inches; skirted miniature cap; T-9 bulb; intermediate shell octal 5-pin base. Maximum ratings are as follows: anode supply voltage, 250 (d-c or peak a-c); anode current, 20 microamperes; ambient temperature, 50°C; luminous sensitivity at color temperature of 2870°K, 30 microamperes per lumen. Mounts in any position. Range: 2000A° to 6300A°. *RCA Victor Division, Radio Corporation of America, Camden, New Jersey.*

Here are the 935's most important features:

- **High ultraviolet sensitivity — 0.02 microamperes per microwatt (at 2537 A°)**
- **No response to infra-red**
- **High vacuum—for high stability**
- **High leakage resistance — 500,000 megohms**
- **Special envelope glass — providing excellent U-V passage**



FREE!

RCA, 466 S. 5th Street, Harrison, N. J.
Please send me the RCA publications checked below:

.....RCA Phototubes—containing 16 pages of helpful information on phototube operation for relays, measurement, and sound reproduction.

.....RCA 935—a technical data sheet on this new RCA ultraviolet-sensitive phototube.

NAME.....

(COMPANY).....

STREET.....

CITY.....STATE.....

The Magic Brain of All Electronic Equipment Is a Tube — and the Fountain-Head of Modern Tube Development Is RCA.

TUNE IN "WHAT'S NEW?"

RCA's great new show Saturday nights, 7 to 8, E. W. T., Blue Network.

RCA ELECTRON TUBES